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# New Technologies in Steel Production: Implications for International Competitiveness

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An Intelligence Assessment



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# New Technologies in Steel Production: Implications for International Competitiveness [redacted] 25X1

**An Intelligence Assessment**

This paper was prepared by [redacted] Office of Global Issues. Comments and queries are welcome and may be directed to the Chief, Civil Technology and Industry Division, OGI, [redacted] 25X1
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# New Technologies in Steel Production: Implications for International Competitiveness [redacted]

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## Key Judgments

*Information available as of 1 July 1985 was used in this report.*

Research under way in Western Europe, Japan, and the United States promises innovative new technologies that will fundamentally change the way steel is made in the 1990s. The two most important of these technologies are:

- *Near-net-shape casting.* Processes that cast liquid steel to shapes close to finished products, eliminating the reheating of semifinished steel and most of its rolling into finished product.
- *Direct smelting.* Processes that would replace the blast furnace and the coking and sinter plants, and would substitute ordinary coal for expensive metallurgical coal.

Another promising technology is the application of plasma torches to steelmaking. Together, these processes could reduce the costs of making flat-rolled steel by 15 to 20 percent. The new processes also would reduce the cost of building a basic flat-product steel mill by at least one-third.

Thus far, Japan probably has mounted the most extensive research and development (R&D) program in near-net-shape casting. Extensive R&D is also under way in the United States that appears to be achieving results equal to or better than Japan's. Most of the R&D in direct iron smelting has been done in Sweden and West Germany; one German process is now on the verge of its first commercial application.

The new technologies are likely to cause considerable industry restructuring as production moves away from large, integrated mills toward smaller, more highly specialized operations because:

- The new technologies will broaden the minimill product line, thus encouraging a new surge in the minimill sector.
- Production in the integrated sector of the steel industry will decline and become increasingly specialized in products still not suited to the minimills.

Third World steel producers also will benefit. Because the new technologies will cost much less to implement than conventional processes, the capital-scarce LDCs will be better able to continue their steel expansion programs.

The countries that aggressively adopt these new technologies have a significant opportunity to enhance their competitive position. Although Japan will be in the strongest position to implement the new processes, it

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probably would gain the least because its steel industry already has achieved some of the cost reductions these technologies will provide. At the other extreme, US firms will have the greatest incentive to invest in the new processes that offer cost-effective ways to overcome their technological lag. Moreover, because of relatively low scrap prices in the United States, expansion of the highly competitive minimill sector is likely to go further here than elsewhere.

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# New Technologies in Steel Production: Implications for International Competitiveness



## Steel Industry in Transition

Steel industry research and development (R&D) is exploring radical new approaches that will fundamentally alter steel production during the 1990s. The new wave of R&D is a response to the steel crisis of the past decade, a crisis that combined weak demand and low prices with soaring costs for energy, labor, capital, and environmental control. The industry also is responding to growing concern over the long-term availability of some of its basic materials, chiefly metallurgical coal and steel scrap. Although some of the new technologies are only now approaching commercialization, we believe they will begin to have a major impact on the steel industry in the early 1990s.

## Technologies for the 1990s

Steel industry R&D is turning increasingly to technologies that will lead to much smaller, more compact, and economical steel mills. An integrated mill of this type, producing basic flat-rolled sheet, would cost at least one-third less to build and would cut operating costs 15 to 20 percent below conventional technology.

### Near-Net-Shape Casting

We believe that near-net-shape casting is the most important new steelmaking technology since continuous casting was developed more than two decades ago. At that time, standard steel technology required the casting of liquid steel into ingots, cooling the ingot, reheating before rolling, primary rolling into semifinished shapes, another reheating, and, finally, rolling into a hot-rolled product. Continuous casting shortened the process by directly casting the semifinished product. Near-net-shape casting would simplify the process further by casting liquid steel directly into shapes close to a finished product. The ultimate objective is to cast the finished shape with no rolling.

Cost reduction is the greatest advantage of near-net-shape casting. Preliminary studies done for the Department of Energy in 1983 indicate that total US operating costs for hot-rolled sheet could be reduced by 10 percent or more:

- Substantial amounts of energy would be saved by eliminating reheating, improving yields, and sharply cutting the amount of rolling required.
- Labor would be reduced as would the cost of refractories, mill rolls, and miscellaneous materials.
- Capital costs would be cut substantially by eliminating reheat furnaces and reducing the size of rolling mills.

In addition to lower costs, some US industry experts believe near-net-shape casting would improve quality by reducing the segregation of impurities that occurs as liquid steel solidifies.



### Direct Iron Smelting

Direct smelting of iron ore promises to replace the blast furnace and the supporting coke and sinter plants as the basic technology for smelting iron ore. The main advantages are lower costs and a cleaner operation. Operating costs are lower because the need to convert coal to coke is eliminated and because ordinary coal replaces expensive and increasingly scarce metallurgical coal. These new smelting procedures would also cut capital costs because direct-smelting units will cost less than a blast furnace per ton of capacity, and there is no need for coking and sintering plants. Elimination of coking operations also rids the industry of one of its most difficult pollution problems (see foldout).



Direct smelters would benefit both minimills and large, integrated mills. Because direct smelters can be economically constructed and operated on a small

## *Major New Steelmaking Technologies*

### *Near-Net-Shape Casting*

*Research and development in near-net-shape casting, under way in the United States, Japan, and Europe for more than two decades, has accelerated in recent years. Although established in nonferrous metallurgy, the casting of thin metal strips has not been successfully transferred to steel.*

*Most near-net-shape casting R&D aims at producing thin slabs—the semifinished product for flat-rolled shapes. Slabs cast in a 1- to 2-inch thickness, compared with today's standard of 6 to 12 inches, would greatly reduce the cost of reheating and rolling to hot-rolled strip. After failing to produce thin slabs when continuous casting was first developed more than 30 years ago, industry research and two decades of production experience in casting thick slabs have led steel technicians to believe that thin slabs are now possible.*

*The more radical R&D seeks to direct cast steel strip in gauges as thin as finished products. Two lines of research are being pursued: extending today's technology for casting semifinished steel to the production of thinner products and utilizing rapid solidification technologies now used to cast steel in very thin sheets of foil. The latter aims at scaling the product up to sheets of commercial thickness. A number of laboratory machines are now able to cast strip as thin as conventional hot-rolled steel. Thus far, however, only narrow strip has been cast, and many experts believe that it will be difficult to scale up. It may also be difficult to achieve the high throughput required by large-tonnage steel production. Most important, no one has demonstrated an ability to cast carbon steel, the industry's basic product, into thin strip with a high-surface quality or with adequate internal structure and mechanical properties—although this has been achieved for stainless steel.*

*The cost-reduction estimate in this study assumes—as many experts do—that casting of thin strip, in its initial stages at least, will require some hot rolling to achieve acceptable surface and other properties. According to most estimates, this casting and rolling mix could cut energy consumption in the US industry by about 5 million Btu per finished metric ton compared with current levels, saving $20 to $25 per ton. A study done for the Department of Energy estimates that the value of labor and miscellaneous materials savings would about equal the energy savings, thus achieving a total cost reduction of $40 to $50 per ton of finished product.*

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### *Direct Smelting*

*The new direct-smelting technologies are essentially an extension of direct-reduction processes available for many years. Conventional direct reduction produces a solid porous material with a 92- to 93-percent metallization called sponge iron or directly reduced iron (DRI). The new processes carry direct reduction further by smelting the DRI to achieve a molten material similar to the hot metal from a blast furnace. The smelting process results in a further separation of iron from the nonferrous elements in the DRI, thus achieving a higher metallization than conventional DRI.*

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*Nearly a dozen direct-smelting processes are under development. Although these processes differ in many respects, all are based on the gasification of ordinary coal (thus eliminating the need for coke) to produce the reduction agent needed to separate the iron from its oxide—the basic chemical process that takes place in the blast furnace. Smelting is achieved in different ways depending on the technology used. The most prominent of the new systems, Korf's KR process developed in West Germany, uses the excess heat generated by coal gasification to smelt the DRI. Direct-smelting systems being developed in Sweden, however, use an electric furnace to smelt the DRI. A quite different direct-smelting system under development by Kloeckner-Werke in West Germany uses a modified basic oxygen steelmaking furnace to smelt iron ore fines. The ore fines are injected through the side of the furnace while oxygen and fuel—usually powdered coal—are introduced through the bottom. The iron ore fines are usually smelted along with steel scrap.*

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scale, they are highly applicable to minimill operations. Small scale also gives flexibility to large integrated mills. Today's integrated mill, which depends on a few large blast furnaces operating close to capacity to maintain efficiency, is greatly disadvantaged when output must be reduced. In contrast, a series of small, direct-smelting units would provide greater flexibility to adjust production. [redacted]

**Plasma Torch Technology**
Plasma torches are created by passing an electric arc through a stream of inert gas. The arc heats and ionizes the gas by causing some electrons to separate from their nuclei. Such plasmas achieve very high temperatures, efficiently converting electric energy into heat. After passing through the electric arc, the plasma state ceases, but the gas stream maintains its high temperature, providing the heat source needed by blast furnaces, electric furnaces, direct smelters, and other steel mill operations. [redacted]

## Key Players and Programs

**Near-Net-Shape Casting**
Research on near-net-shape casting is vigorously pursued in Western Europe, Japan, and the United States. [redacted]

[redacted] the Japanese are taking a fairly conservative approach, focusing most of their resources on a thin-slab-casting system rather than on strip casting. Although slabs cast in 1- to 2-inch thickness, compared with today's 6- to 12-inch slabs, would save substantial amounts of energy and rolling, the ultimate gains from casting strip would be much greater. Much of the current Japanese research concentrates on adapting a technology for casting nonferrous metals developed in the United States by the Hazelett Strip-Casting Corporation. Like Japanese R&D, European R&D also is focusing on thin slab 25X1 casting. The Swiss firm Concast has been working on such a system since the mid-1970s, and West Germany's Mannesmann-Demag also has been active for some years. In addition, Krupp in West Germany, Danieli in Italy, and British Steel in the United Kingdom are working on this technology; US Steel and Bethlehem Steel are working jointly to develop the Hazelett caster into a thin-slab-casting system for steel production. [redacted] 25X1

Despite the intensive activity abroad, there is a good chance that the first commercial thin-slab-casting 25X1 system will be built in the United States using US technology. In mid-1985, after an extensive survey of the Japanese and European alternatives, a major US minimill operator concluded that the Hazelett caster offered the best hope for a near-term solution to the thin-slab-casting problem and has purchased one for testing. The tests are expected to take about a year. If the Hazelett technology measures up to expectations, 25X6 the company plans to install the caster in a new mill, 25X6 which probably would be the world's first flat-rolling minimill using thin slabs. [redacted] 25X1

[redacted] a commercialized thin-slab-casting system is not likely from a Japanese or European company for another three to five years. 25X1 In Japan, [redacted] Sumitomo is casting slabs 1 to 2 inches thick in batches up to 40 tons. 25X1 Nippon Steel and Kawasaki Steel also are casting thin slabs experimentally but on a much smaller scale. [redacted] quality is good enough for the 25X1 basic sheet grades used in construction and some containers. In Europe, the Swiss firm Concast—oldest builder of continuous casting equipment—told US Embassy Bern that it has developed a thin-slab-casting process and is ready to build a pilot plant.

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**Table 1**
**Innovative Steel Technologies**

| Technology | Description | R&D Key Countries and Companies | Major Advantages | Time Scale to Commercial Application |
|---|---|---|---|---|
| Near-net-shape casting | Processes to extend today's continuous casting of semifinished steel to cast either a thin slab 1 to 2 inches thick or to directly cast steel strip 0.1 inch in thickness. | **Japan**. Nippon Steel, Kawasaki Steel, Sumitomo Metal, Mitsubishi, Hitachi, and others.<br>**West Germany**. Mannesmann-Demag, Krupp<br>**Switzerland**. Concast<br>**Italy**. Danieli<br>**United Kingdom**. British Steel Corporation | For hot-rolled sheet:<br>• 15- to 20-percent reduction in operating cost<br>• 33-percent reduction in capital cost<br>• Better emission control | Thin slabs, three to five years; thin strip, 10 to 15 years. |
| Direct iron smelting | Processes to replace blast furnaces and coking and sinter plants. Iron reduction is carried out in a separate chamber from smelting, allowing gasification of ordinary coal both to create reduction agent and heat needed for smelting. | **West Germany**. Korf Engineering<br>**Sweden**. SKF Steel Engineers, Boliden, Stora Kopparberg<br>**Japan**. Kawasaki Steel, Sumitomo Metal<br>**Netherlands**. Hoogovens | As replacement for a blast furnace:<br>• 15-percent reduction in operating cost<br>• 25- to 30-percent reduction in capital cost<br>• Major advance in emission control | First commercial units may be under construction within a few years. |
| Plasma technology | Application of plasma torches to steelmaking. Plasma torches efficiently convert electric energy to head by ionizing a gas stream. The hot gas is then available for use in various steelmaking processes. | **Austria**. Voest-Alpine<br>**Belgium**. Cockerill-Sambre<br>**Sweden**. SKF Steel Engineers | Greater efficiency in:<br>• Electric furnaces<br>• Blast furnaces<br>• Direct-smelting processes<br>• Mill waster management | Some application in electric furnaces is likely within a few years. |

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West Germany's Mannesmann-Demag is doing comparable work, [redacted] 25X1

The United States is generally taking a bolder approach to near-net-shape casting than its international competitors. Most research is focused on the direct casting of a product roughly equivalent to hot-rolled strip, the industry's primary flat-rolled product. This is a more difficult challenge than thin slab casting because the quality requirements are much higher. Research is under way in several major US steel companies and at the Battelle Memorial Institute and the Massachusetts Institute of Technology. Allegheny Ludlum now has a process to cast thin stainless steel strip that yields a high-quality product with only limited cold rolling. Many engineering problems remain, however, in adapting the process to carbon steel, in moving from narrow to commercial-width strip, and in scaling up to large-tonnage operations. [redacted] 25X1

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### Direct Iron Smelting

Most Western R&D is taking place in West Germany, Sweden, and Japan. In Germany, Korf Engineering has developed the KR (Coal Reduction) direct-smelting system that uses a fluidized bed to gasify ordinary coal and then introduces the gas into a conventional direct-reduction shaft furnace where it reduces the iron ore, or concentrate, to sponge iron. The sponge iron is then fed into the smelting chamber where excess heat from the gasification process smelts it to hot metal. The waste gas discharged from the KR process recovers possibly as much as 60 percent of the initial energy input and is available for use in other parts of the mill or possibly as an industrial feedstock. Close variants of the KR process have been developed by the Dutch steelmaker Hoogovens and by Midrex in the United States. In Japan, the Sumitomo process is modeled after the KR system.

Swedish firms have developed three separate direct-smelting processes: Boliden's Inred, Stora Kopparberg's Elred, and SKF Steel Engineer's Plasmasmelt. These processes differ from the KR system primarily in the use of electric furnaces for the smelting stage. Elred and Inred use waste heat and gas from the reduction and smelting process to generate all the needed electric power; the Plasmasmelt process requires significant amounts of additional electricity. Kawasaki's direct-smelting technology is similar to SKF's Plasmasmelt.

Korf Engineering successfully operated a pilot KR plant in Kehl, West Germany, from 1982 until its shutdown in early 1985; and steelmakers worldwide tested it. Despite these tests, several important questions remain concerning the KR system's economics that probably can not be resolved without several years of continuous production in a commercial or demonstration plant. This now seems likely to occur in South Africa where Korf sold its first commercial unit in 1985. South Africa's chief steelmaker, ISCOR, will begin KR operations by 1987-88 as replacement for old blast furnace and coke oven capacity. Korf is also negotiating with other steelmakers for additional sales, including a possible sale to North Korea. In Sweden, Boliden's Inred process has attracted serious interest from at least one potential buyer. A report from the US Consul Madras indicates that the Indian Government is considering one or more of the Swedish processes for a new integrated mill instead of the conventional Soviet technology originally planned. In Japan, Sumitomo Metal has announced its intention to build a plant to demonstrate its direct-smelting technology.

**Plasma Torch Steelmaking**

Although the United States accounts for much of the basic laboratory work in plasma torch technology, most applied R&D is being done abroad. Austria's Voest-Alpine, for example, has an electric furnace that uses plasma torches in place of the usual electrodes. In Sweden, SKF uses plasma technology as a major element in its Plasmasmelt direct-smelting system, and Belgium's Cockerill-Sambre has put plasma torches in the tuyeres of a blast furnace. Although industry experts believe its large electric power re- 25X1
quirement clouds the outlook for plasma technology in steelmaking, we believe the technology will find specialized uses in the industry, particularly in areas with low electric power rates. 25X1

**Who Will Lead in Application?**

Once proved in theory, the difficult task of moving from pilot plant to full-scale production begins. We believe this transition could be especially difficult, time consuming, and expensive for the capital-intensive steel industry. For these reasons, we think many firms will be reluctant to take the lead in 25X1
bringing these technologies on line. Those companies seizing the initiative, however, have a unique opportunity to enhance their competitive position and slash their production costs. 25X1

Japanese steelmakers have been the most aggressive in bringing new technologies on line, a key reason why they are now the lowest cost producers. US steelmakers, in contrast, have been slow to apply new processes, a fact that helps account for the industry's current technological lag. We believe, however, this attitude may be changing. Trade journal reports and our discussions with industry experts indicate aggressive US interest in the new processes. In addition to the thin-slab-casting project already discussed, we believe there is a good chance that a US company also will be among the first to build a commercial KR direct iron smelter. 25X1

The availability of investment funds will be a key determinant in the widespread application of these new steelmaking technologies. Because of its substantial financial resources, we believe the Japanese steel

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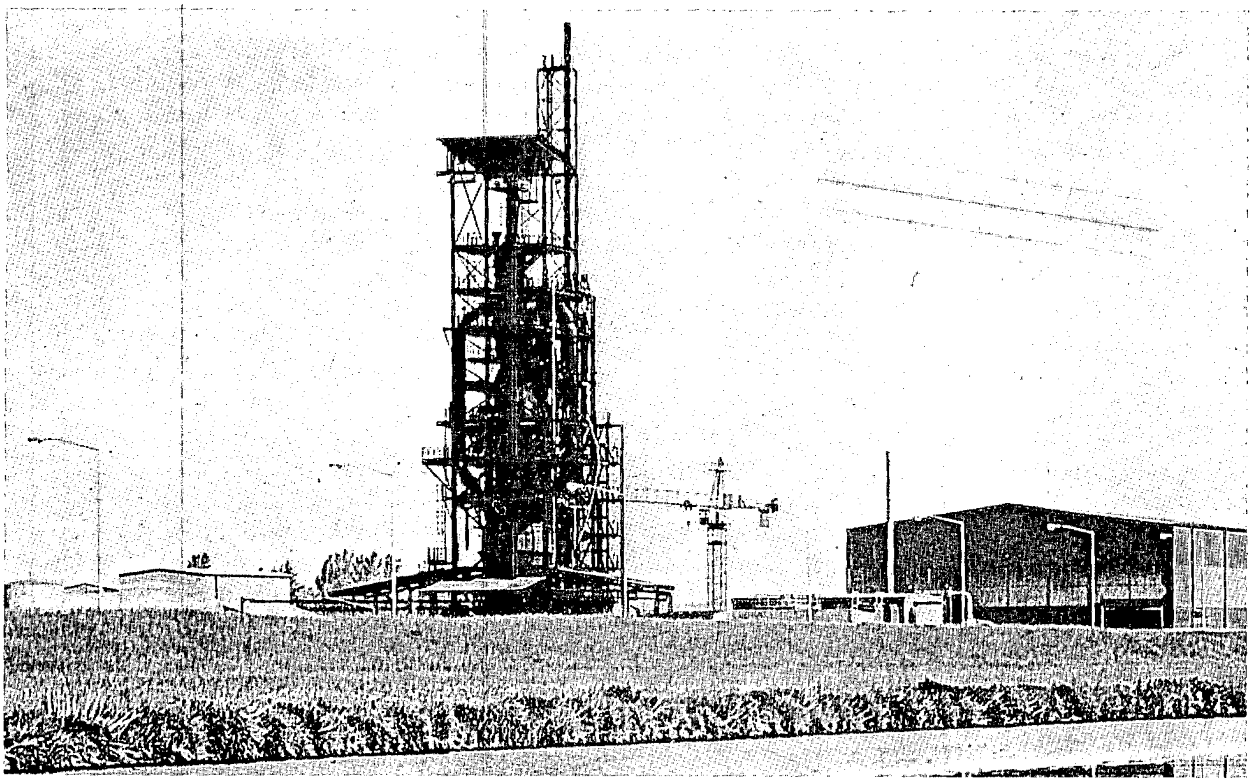

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*The KR pilot plant at Kehl*

industry will be better able to exploit the new technologies than its major rivals. Japan's steel industry has been profitable during most of the crisis years because it generally has the newest facilities and is the low-cost producer. Continuing modernization, moreover, should further strengthen its position.

At the other extreme, we believe the EC probably will be in the worst position to take advantage of the new technologies. Although modernization and rationalization have brought the EC industry to the verge of profitability, it remains the weakest of the major steel industries. Moreover, the EC may be at the point of cutting back or even eliminating the subsidies that have sustained much of its steel investment over the past decade. Further, the EC steel industry is particularly vulnerable to any fall in the US dollar. The EC steel market is fiercely competitive, and lower domestic currency earnings from exports because of a weaker dollar would likely lead to a cut in domestic steel prices as well.

Financially, the US steel industry probably will occupy a position between those of Japan and the EC. Through most of the crisis years, the US industry has performed somewhat better than that of the EC. Moreover, cost-reduction efforts are slowly improving the industry's competitive position, which would benefit further from dollar depreciation. Some of this benefit, however, could be lost if voluntary import restraints negotiated with major foreign steel suppliers are phased out. The current program to hold steel imports to 18.5 percent of US consumption, for example, is scheduled to expire in late 1989.

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Beyond these considerations, it is difficult to project the steel industry's financial ability to exploit technologies that will not come on line until the 1990s. If the steel crisis of the past 10 years continues unabated, investment capital will continue to be scarce. The

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***Improved Steel Market***

*We believe that the market for steel should improve somewhat during the second half of the 1980s with the gradual phasing out of a number of the factors that have helped depress demand over the past 10 years. These include:*

- *The decline in steel inventories.*
- *The decline in scrap generation by important steel-using industries.*
- *The depression in world shipbuilding.*
- *The downsizing of passenger automobiles.*
- *The neglect of infrastructure investment in many developed countries.*

*Many long-term negative factors will remain, however, as economic activity continues to shift toward services and high-technology industries with small steel requirements and as further substitution of other materials for steel takes place. Consequently, we believe the steel market improvement will be modest with the declining trend at best reversing to no more than very slow growth.*

steel market in the developed countries still appears to be weakening. We believe, however, that this trend may bottom out in the next few years as some of the special factors that have depressed demand gradually are worked off.

**Economic Implications:**
**Industry Performance and Restructuring**

Innovative steel technologies will provide new opportunities for profitable investments, trigger further restructuring of the industry toward the minimill sector, and give a new boost to Third World steel development. Although the changes will be fundamental, they will take place slowly. Steel has a huge, costly, and long-lived capital stock, and the time required to shift from one technology to another normally is measured in decades rather than in years.

**Improved Profitability**

***Near-Net-Shape Casting***. Industry studies suggest, and we concur, that near-net-shape casting appears to offer the highest potential return on investment of any of the new technologies. One study has estimated, for example, that a strip-casting system combined with some hot rolling could reduce operating costs about $50 per metric ton on an investment of possibly as low as $100 per ton. On the basis of a 25-year lifespan, this indicates a better than 25-percent aftertax discounted cash-flow return on investment. Yields could be higher if tax advantages, such as investment tax credits, accelerated depreciation, and deductions for interest paid on borrowed funds remain available. 25X1

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***Direct Smelting***. Although payback for the direct-smelting processes appears less favorable than for near-net-shape casting, the savings can nevertheless be significant. The KR system, for example, is likely to prove the most effective of the group and is estimated by industry analysts to save $25 to $30 per metric ton of hot metal in operating costs, compared with today's blast furnaces. With required investment estimated to be somewhat more than $200 per ton of hot metal produced and an aftertax profit improvement of only $15 per ton, however, returns on investment are inadequate to justify construction except in the case of an older plant replacement. Compared with a new blast furnace costing about $300 per ton of capacity, a KR plant—which also has significantly lower operating costs than a conventional blast furnace—is the clear choice. 25X1

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We believe the KR system is particularly attractive as a replacement for old coking plants. Coking capacity currently costs approximately $150 per ton of hot metal (the cost per ton of coke output is about $300, but only half a ton of coke is needed to produce a ton of hot metal in an efficient blast furnace). Thus, with only a moderate increase in capital outlays, a firm can cut operating costs significantly by replacing both the coke plant and the blast furnace with a KR plant.

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**Table 2**
**New Steel Technologies: Expected Operating Cost Savings for Hot-Rolled Sheet**

| Technology | *US $ Per Ton* | *Percent of Total Cost* |
|---|---|---|
| **Near-net-shape casting** | **45** | **10.0** |
| Energy | 23 | 5.0 |
| Labor | 11 | 2.5 |
| Materials | 11 | 2.5 |
| **Direct iron smelting** | **25** | **5.0** |
| Energy | 13 | 2.5 |
| Labor | 12 | 2.5 |

This would be of particular benefit to US and European industries because of their large amounts of overage coking capacity. Other factors may further improve the KR's economics. The Hoogoven's process, for example, modifies the system to fit into the shell of an old blast furnace, improving its economic viability by reducing construction costs by one-third, according to one industry expert. The system's economics will be further improved if natural gas prices continue rising; higher prices would increase the value of the off gas produced by the process, an important part of its economic advantage.

**Industry Restructuring**
We believe the new steelmaking technologies will be a major force in restructuring the steel industry toward smaller and more highly specialized units. Perhaps the most notable changes will occur as the minimill sector expands and consequently causes further contraction in the integrated sector of the industry.

***Minimills***. Near-net-shape casting will spur industry restructuring by shifting more steel production to the minimills. Until now, the minis have been limited almost exclusively to the production of bars and light structural shapes. If so confined, most industry experts believe that the minis will be unable to increase their market share much further. The minimills have been unable to produce flat-rolled products except on a small scale because the huge mills needed to roll conventional slabs are not feasible for small electric furnace operations. Thin slab, or directly cast strip, however, will require much less rolling, and we believe near-net-shape casting will bring the minis into the flat-rolled business in a big way. Most analysts expect the minis to begin with basic grades of hot-rolled strip and sheet, which primarily are used for decking, siding, and containers, such as drums and pails. Past history suggests, however, that the minis will move gradually to more sophisticated sectors of the market as the technology develops.

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The price of scrap will have a critically important impact on the speed and breadth of this trend. Based on the average scrap price prevailing in early 1985, minimills in the United States probably could produce hot-rolled sheet for $75 to $100 per ton less than today's integrated mills because of the low cost of their raw materials, the lower operating costs of a thin-slab- or strip-casting system, and lower wages. This advantage will erode, however, if further minimill expansion drives up scrap prices. At today's technology, we estimate that a scrap price of $130 per ton, compared with $80 at the beginning of 1985, would wipe out the minimill's advantage, assuming no change in the cost of hot metal from blast furnaces.

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A rise in scrap prices is likely to be offset, in part, however, by ongoing advances in electric furnace technology. As the cost of smelting and refining scrap in an electric furnace continues to decline relative to the cost of refining hot metal in a basic oxygen furnace, the minimills will be able to tolerate higher scrap prices without losing their competitive edge. Moreover, other new technologies, such as the Kloeckner KS process or the Energy Optimizing Furnace (EOF), developed by Korf, may lead the minimills away from electric furnaces, freeing them from the need for high-cost electric power. (See appendix for a discussion of new electric furnace technologies and the KS and EOF processes.)

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***The Integrated Mills***. As the minimills continue to expand, the integrated sector probably will be forced into further contraction because it is unlikely that growth in demand will be sufficient to absorb the new capacity. Because the oldest and least efficient integrated mills will be the first to close, marginal costs of production will decline until a new equilibrium is achieved between the integrated and minimill sectors. [redacted]

As the integrated sector contracts, we believe it will undergo some change of function as well. We believe the largest integrated producers will concentrate on cold rolling, tin plating, galvanizing, and other specialized finishing operations not well suited to the minimill. Other integrated mills will abandon iron and steelmaking altogether to become rerolling operations using semifinished steels supplied by other mills—a trend already in its nascent stage. Independent cold-rolling and finishing mills could also develop using hot-rolled coil supplied by either the integrated or the minimill sectors. Finally, some minimills will become small, integrated operations in their own right by the installion of direct iron smelting capacity. [redacted]

***The Third World Steel Industry***. We believe the new steel technologies will be introduced steadily in the Third World as it pushes to build new mills to meet its growing steel requirements. Although financial difficulties have slowed expansion, most industry experts continue to believe that the LDCs will increase capacity 30 to 35 percent by the end of this decade. The new technologies could be particularly advantageous in that they will reduce steel mill construction costs and thus ease the financial burden of steel industry expansion in these capital-scarce countries. Direct-smelting and near-net-shape casting technologies are especially interesting to the LDCs for this reason. [redacted]

Some of the new technologies will be of particular benefit to selected LDC steel industries because of energy-related issues. Plasma technology could benefit those LDCs with an abundance of cheap hydroelectric power. Direct smelting will appeal to heavy importers of coal or those countries with little or no metallurgical coal. The largest LDC steel producer, Brazil, which has large hydroelectric resources but little metallurgical coal, would strengthen its competitive position by the application of both direct iron smelting and plasma technology. Direct iron smelting also would improve the already strong position of the two most competitive LDC steel producers, South Korea and Taiwan, which have virtually no domestic coal resources. Finally, LDCs with abundant and cheap natural gas may find new export opportunities for their directly reduced iron as the innovative technologies expand minimill production in the developed countries. Growing minimill steelmaking will generate added demand for scrap and for directly reduced iron as well because it is the chief substitute for scrap. [redacted]

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## Outlook for Competitiveness

We believe the industries that aggressively adopt the new technologies have an opportunity to enhance their competitive position. The incentive to invest in innovative new processes, however, is likely to vary significantly from one industry to another. Consequently, the spread of the new technologies probably will lead to some shift in the relative competitive position of the major steel producers. [redacted]

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[redacted]

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*The US steel industry's* return on investment in the new technologies is likely to be greater than any of its major competitors because it is currently the highest cost producer. Near-net-shape casting, in particular, offers US steelmakers a profitable way to replace their aging and generally antiquated rolling-mill capacity. Direct iron smelting will also provide benefits as a cost-effective replacement for badly deteriorating coking capacity and old blast furnaces. Minimill expansion should also bring a new infusion of state-of-the-art technology into the industry. Although a similar trend will occur in other countries, the process may be more limited abroad than in the United States. Scrap prices are already relatively high in

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***The Soviet Steel Industry and the New Technologies***

*We have no evidence that current Soviet R&D programs include any of the processes discussed in this paper. Nevertheless, we believe that the new technologies will be of considerable interest to the Soviet steel industry and that they could offer the Gorbachev regime a means to improve sharply the performance of this crucial industrial sector.* 25X1

*Direct iron smelting is likely to be the most attractive of the new processes to Soviet steel planners. Shortages of coking coal have constrained Soviet steel production for some time, and we expect this problem to grow worse in the years ahead. Since direct iron smelting eliminates the need for coke, the Soviet industry is likely to look carefully at the new process as a way to mitigate and eventually eliminate its need for metallurgical coal.* 25X1

*On the energy front, both direct iron smelting and near-net-shape casting should interest the Soviet steel industry because of the savings these processes offer. We estimate, for example, that together these technologies would save the US industry 7-8 million Btu of energy per ton of finished product, and the savings are likely to be greater in the USSR. Near-net-shape casting, moreover, would have the extra attraction of upgrading the quality of Soviet finished steel products, an important goal for the upcoming five years.* 25X1

*Finally, the new technologies probably will recommend themselves to Soviet planners because they cost less per ton of capacity than conventional processes. The Soviets have indicated that half the funds to be invested in the steel industry over the next five years are aimed at rebuilding and renovating existing mills. Soviet steel authorities can be expected to be attracted to any technology that not only cuts operating costs but also stretches investment funds to the maximum.* 25X1

most other Western countries, and any further increase in price because of minimill expansion will eliminate the sector's cost advantage faster abroad than in the United States. 25X1

We believe the situation of the *EC steel industry* will be closer to that of the United States than to that of Japan. EC steel capacity is somewhat newer than that of the United States, and the EC has scrapped more of its old plants than either the United States or Japan. Nevertheless, the EC's real production costs remain close to those of the US industry, and the region will continue to be under heavy pressure to find new and innovative ways to cut cost and restore profitability. The major EC problem may be the availability of investment funds; the key element being how much additional funding EC governments are willing to supply. 25X1

The shift in relative competitiveness, in any event, will be moderate and slow in coming. Historically, steel technologies have been available throughout all producing countries, and we believe this will be true for the new technologies as well. Moreover, because of the industry's size, the basic changes to be expected from the new processes will occur gradually, giving players time to adjust to new circumstances. If a given company or industry is too cautious in moving toward the new processes, however, its competitive position could deteriorate seriously, leading to a declining financial position and loss of market share. 25X1

# Appendix

## The Near-Term Steel Technologies: Building a Bridge to the Innovative Technologies of the 1990s

### Continuous Casting

Many steelmen believe that extensive R&D, together with 20 years of production experience, has brought conventional continuous casting technology to a very high state of development and that little further progress is likely. In terms of application, however, continuous casting has some way to go. Even in Japan, where the process has been rapidly adopted, continuous casting accounts for only 60 percent of semifinishing capacity. In the EC, continuous casting is about 55 percent of capacity, and in the United States it is 35 percent. By 1990, however, industry experts expect the continuous casting share to rise to 80 percent, 70 percent, and 50 percent, respectively. [redacted]

### Electric Furnace Steelmaking

Electric furnaces account for 30 percent of total steel production in the developed countries, up from less than 20 percent 10 years ago. Electric furnace technology also has developed rapidly and reduced the time and power input required to melt a given amount of scrap. This has been accomplished chiefly by the introduction of water-cooled wall and roof panels, which permit an increase in the power input, and by the use of fuel and oxygen injection to improve furnace thermal efficiency. Application of these technologies will spread as existing furnaces are retrofitted. The use of waste furnace heat to preheat the scrap charge and to further increase furnace efficiency is increasing, and we believe it will continue to grow. Other new technologies include direct current furnaces, water-cooled and coated electrodes, bottom pouring, and possible continuous charging. [redacted]

### Basic Oxygen Furnace (BOF) Technology

Experiments have been conducted for some time with various combinations of top and/or bottom blowing to replace conventional top blowing in BOF practice. Adoption of the new blowing technologies has been limited, but their use is likely to increase. Existing furnaces can be retrofitted at a moderate cost thus increasing furnace yields (liquid steel output to hot metal and scrap input). A more recent bottom-blowing variant—the KS system developed by Kloeckner-Werke in West Germany—also injects pulverized coal or coke into the furnace to increase the scrap-to-hot-metal ratio in the furnace charge. It offers cost savings as long as scrap is cheap relative to hot metal and gives an integrated producer the flexibility to shift its raw material mix as scrap prices vary relative to iron ore. Because the process can take a 100-percent scrap charge, it may offer an alternative to the electric furnace for minimill operations. Another modification to BOF practice now receiving limited trial involves the use of a change vessel. This system could increase the productivity of a given BOF shop by 5 to 10 percent with a moderate investment for additional machinery and space. Under conventional practice, a furnace is shut down about every three months (at full output) for refractory reline, a job that takes some 10 days. With a change vessel, a furnace needing relining is replaced by the spare vessel and the BOF stand continues to operate. [redacted]

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### Open-Hearth Technology

A potentially important modification of the old open-hearth furnace has been developed by the Korf organization at its Brazilian subsidiary, Siderurgica Pains. The new system, called the Energy Optimizing Furnace (EOF), injects powdered low-sulfur coal and oxygen through tuyeres directly into the metal bath. According to Korf, this practice enables the furnace to refine efficiently various combinations of hot metal and scrap. Perhaps most important, Korf believes the EOF can be an efficient scrap melter and an alternative to the electric furnace. Korf is now preparing to demonstrate this possibility by installing an EOF in a

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new minimill located in Connecticut. If this venture is successful, it could further improve the minimill's competitive advantage over the integrated mill. [redacted]

## Ladle Metallurgy

This process ranges from simple to very complex. Used traditionally by specialty steel producers, ladle metallurgy is being adopted rapidly by carbon steel makers as a relatively inexpensive way to upgrade product, improve productivity, and achieve a better link between BOF and continuous casting operations. Ladle metallurgy transforms the vessel used to move liquid steel from the steelmaking furnace from a simple transfer vehicle to one that advances the refining process. Degassing, decarbonization, desulfurization, and alloying are all functions now performed in the ladle. Techniques range from simple stirring devices to help degas the liquid steel to sophisticated processes that transform the ladle into a furnace. [redacted]

## Rolling Mill Technology

Among the various developments in rolling technology, the most noteworthy probably is the trend toward smaller hot-rolling mills. New coil-box and reversing-stand technologies allow a scaling down of the hot-strip mill from today's large, very expensive operations. This trend will be reinforced to the extent that near-net-shape casting is brought to fruition. Smaller hot-strip mills would yield important capital and operating cost savings to integrated plants needing to replace aging equipment. More important, perhaps, it would open the way to strip and sheet production by the minimill sector. [redacted]

Recent improvements in Steckel mill technology also may prove to be a major new development. Steckel mills reduce slabs to hot-rolled strip by successively passing the steel back and forth through a single rolling stand rather than sending it in a single pass through a continuous mill of 10 or more stands. The Steckel mill has the great advantage of compactness and low cost but has never been able to produce a high-quality product and has generally been used only to produce narrow strip. Now a major US equipment builder believes it has upgraded this technology to achieve much higher quality and is building a mini rolling mill to produce hot-rolled strip and plate to demonstrate its achievement. If this venture is successful, it will mean that minimills may be able to break into the flat-rolled sector of steel production whether or not near-net-shape casting becomes a reality. [redacted]

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## Coal-Based Direct Reduction

Direct-reduction technology is well established. About 8 million tons of directly reduced iron (DRI) is produced annually in the non-Communist world, mostly as a supplement for scrap in electric furnaces. Thus far, however, natural gas or fuel oil has remained the only practical reduction agent for DRI, and the rising cost of these fuels has almost driven DRI production from the developed countries and confined it to those less developed areas with extensive petroleum resources. Coal-based direct reduction has been available for a decade but has been plagued by technical problems. Recently, however, several suppliers appear to have improved the technology's reliability. Nevertheless, coal-based DRI still is not competitive with today's cheap scrap or with DRI from areas with inexpensive gas and oil supplies. This is likely to change in the future as electric furnace steelmaking increases and pushes both scrap and DRI prices higher. [redacted]

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## Hot Charging and Direct Charging to the Hot-Rolling Mill

This technology is now being applied limitedly, particularly in Japan. Despite its difficulties, it probably will increase in time because of the significant energy saving to be achieved. Conventional practice permits steel slabs to cool completely for inspection and surface reconditioning when necessary. Hot charging allows only some cooling, followed by a minimum of reheating before charging to the rolling mill. Direct charging sends the semifinished steel directly from the casting machine into the rolling mill with no

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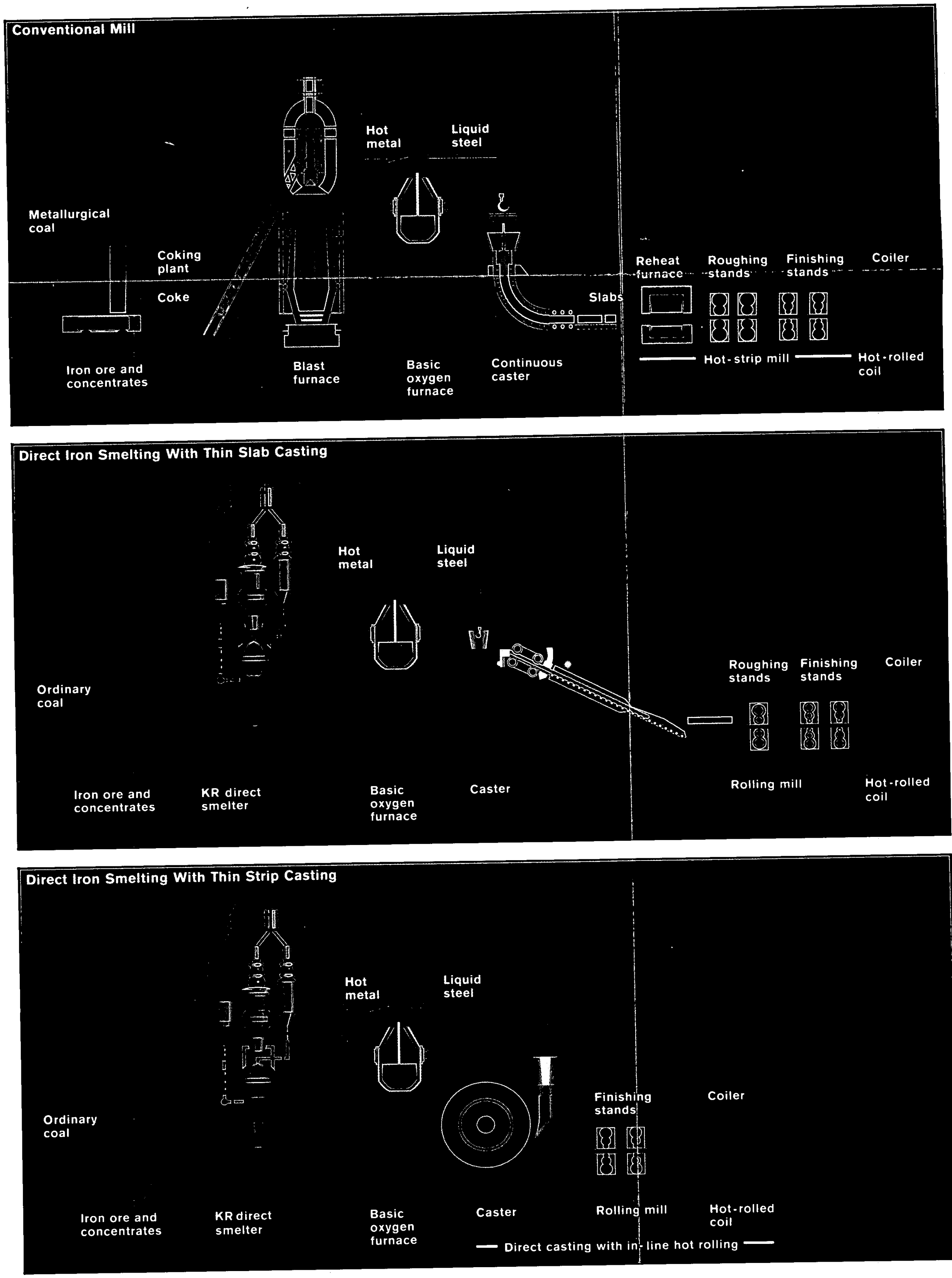
reheating. Both hot charging and direct charging require new technologies to assure the quality of semifinished steels because conventional inspection and reconditioning are not possible. These new technologies are still only in the early stages of development, and their current inadequacy constitutes one of the major barriers to the spread of direct and hot charging. Direct charging also requires close coordination between the operating rate of the casting machine and that of the rolling mill, a link that is difficult to achieve. [redacted] 25X1

**Process and Quality Control Sensors**

The major steel industries are developing high-technology sensing devices to replace the rather crude tools now used to monitor many important steel mill operations and the physical state of semifinished steels moving through the mill. Computer technology allows the processing of the large volume of data needed to precisely control steel mill operations. Although computers have found wide application throughout the steel industry, their effectiveness in some critical areas has been limited by a lack of the sensing devices needed to collect the basic data they require. [redacted] 25X1

**Alternate Iron Smelting, Steel Casting, and Hot Rolling in Flat-Rolled Integrated Mills**

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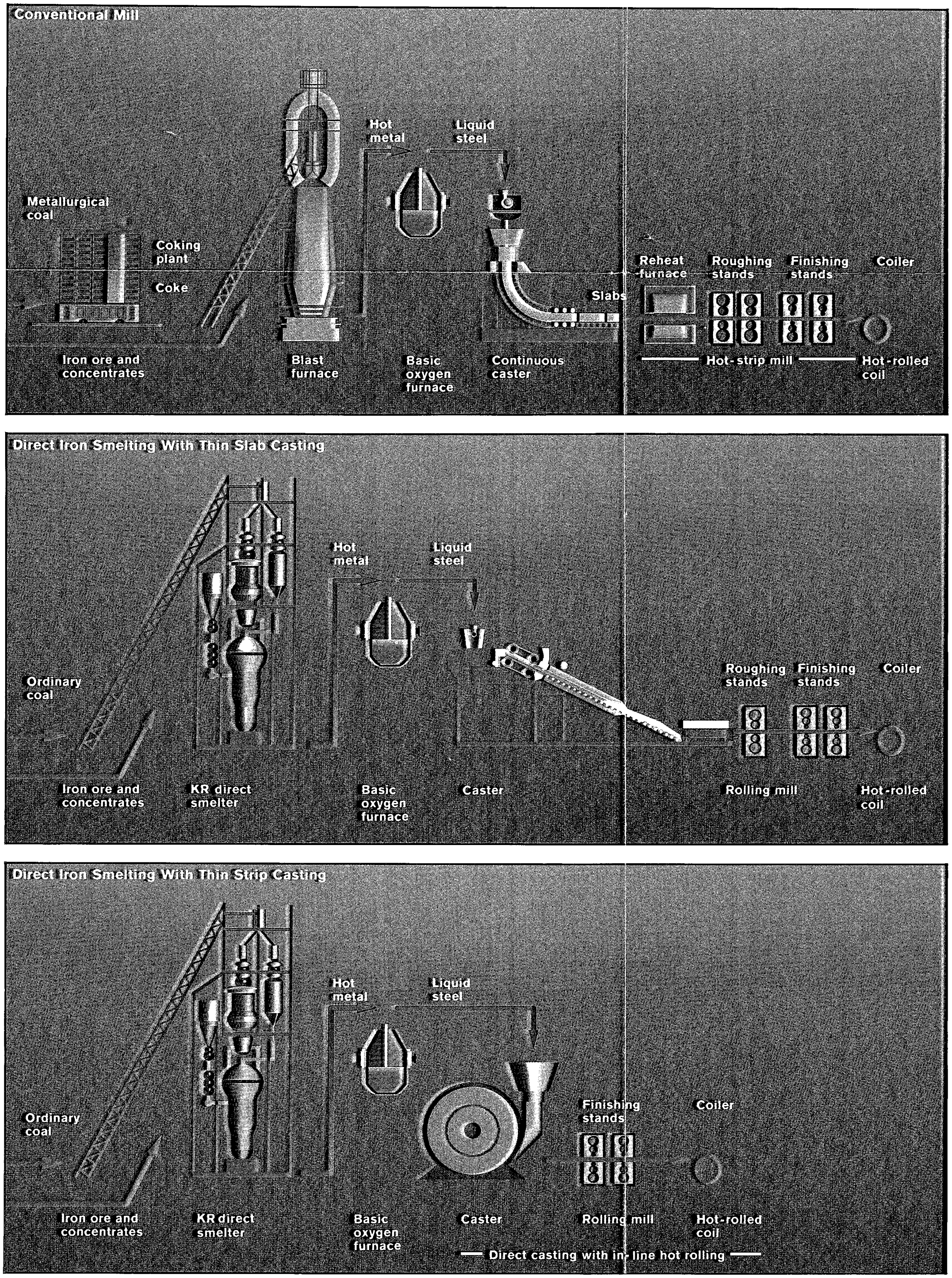
**Alternate Iron Smelting, Steel Casting, and Hot Rolling in Flat-Rolled Integrated Mills**

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