CHAPTER 8

Technology and Industry Restructuring

Contents

List of Tables

List of Figures

CHAPTER 8

Technology and Industry Restructuring

Summary

The structure of the domestic steel industry is changing. What is meant by structural change? Broadly speaking, structural changes in industries refer to permanent changes in the character and competitive positions of industry participants. Technology mixes, supply-demand relationships, geographical patterns of company locations, costs of entry into the industry, and raw material use may all be components of a structural change.

Structural changes can result from both regulatory and technological influences.[1] For example, deregulation changed the nature of the U.S. securities industry by freeing commission rates; this led to many mergers and acquisitions within the industry, an increased concentration of capital, and the virtual elimination of some types of companies. Similarly, deregulation of the airline industry is clearly bringing about a rapid growth of small regional carriers and the need for new Government policies for this industry segment. An example of technology-related structural change, on the other hand, is in the watch industry, where the introduction of solid-state technology by American and Japanese companies brought about a permanent change in the industry. In 1970, the Swiss had a 70-percent share of the world market; by the late 1970's, it was falling below 30 percent. Entirely new companies had entered the industry with new manufacturing technology and new products.

Permanent structural changes within an industry alter the impact of Government policies on the industry and create new needs that may require new policies. But even profound structural changes are difficult to recognize while they are taking place. One reason why OTA has examined the steel industry as separate segments was to be able to determine whether structural changes are occurring in the steel industry and, if so, to analyze their nature. OTA found that restructuring is in fact taking place, and that it may accelerate because of a number of factors, including new technology. This restructuring consists of growing competitiveness, expansion, and profitability of the two smaller segments of the industry: the nonintegrated carbon steel producers and the alloy/specialty steelmaker. As a result, traditional market shares in steel are shifting, and the industry is becoming decentralized.

Part of the emergence of the two smaller steel industry segments can be attributed to internal, technical adjustments within individual companies; that is, the extent to which companies match the nature of their production (its type and scale) with the type and quantity of products they manufacture. For example, the unprofitable integrated companies may be attempting to make too wide a variety of products, using steelmaking technology better suited to large-volume production of a few commodity products. Nonintegrated and alloy/specialty companies generally have a good match between production technology and product mix, and this enhances their profitability.

External forces have played some part in its restructuring. Demands for alloy/specialty products have increased. At the same time, nonintegrated companies in particular have not been reluctant to expand their product lines and move into markets dominated by integrated producers. The structure of the steel market reflects these factors. The market share of integrated producers is declining and, by 1990, it could drop from the present

[1]R. R. Osell, "Structural Versus Cyclical Change—Implications for Strategic Planning," paper presented at American Institute of Mining, Metallurgical and Petroleum Engineers annual meeting, February 1979.

85 percent to about 70 percent. Nonintegrated steelmaker have tripled their output in the last decade. In 1978, they accounted for 13 percent of domestic shipments, and if adequate ferrous scrap and electricity are available they could account for 25 percent by the end of the 1980's. Because the domestic consumption of alloy/specialty steels is increasing at a rate about double that of carbon steels, alloy/specialty production is likely to expand by about a third during the next decade. (Table 96 presents recent production and financial data for the three industry segments.)

New technologies have and will continue to influence the shift in the structure of the steel industry. Electric furnaces and continuous casters have reduced production costs and simultaneously enabled the small companies to capitalize better on local markets for their products. It can be argued that technological changes would also enable the integrated companies to take better advantage of their process capabilities, but substantial obstacles deter the adoption of such changes. These obstacles include inadequate capital and conservative management,

The most important future technological developments for nonintegrated producers will be the introduction of rolling mills to make flat products, such as strip, and the use of direct reduced iron (DRI) to supplement scrap and facilitate the production of higher quality steels. The alloy/specialty steelmaker have excellent technological and cost competitiveness and potential for exporting their technology-intensive steels.

Table 96.—Summary Data on Steel Industry Segments, 1978

	Raw steel[a]		Steel shipment[a]		Return on Invest ment[b]	Steel only—pretax profits ($/tonne shipped)[b]	Employment costs ($/tonne shipped)[c]
	1,000 tonnes)	Percent	(1,000 tonnes)	Percent			
Integrated	107,889	87	75,522	85	-6.9	$9.60	$209
Nonintegrated	12,274	10	11,291	13	12.3	31.60	138
Alloy/specialty	4,125	3	2,014	2	11.1	81.33	341
Total[d]	124,288	100	88,827	100	7.3	$22.00	$163

SOURCES. [a]Based on data and approximations provided by AISI OTA has assumed an average yield for Integrated companies of O 70 and for nonintegrated companies of 0.92
[b]From table 23
[c]From table 23
[d]From AISI, financiat data includes nonsteel activities.

Internal Adaptation

An analysis of process and product stages of manufacturing companies permits a useful understanding of differences among them. A given company or industry segment is either process- or product-oriented; that is, process-focused firms tend to find the market for their product and process, while product-focused companies try to fit the best process and product to market opportunities:

> Companies in the major materials industries—steel companies and oil companies, for example—provide classic examples of process-organized manufacturing organizations. Most companies that broaden the span of their process through vertical integration tend to adopt such an organization, at least initially. Then again, companies that adopt a product- or market-oriented organization in manufacturing tend to have a strong market orientation and are unwilling to accept the organizational rigidity and lengthened response times that usually accompany centralized coordination.
>
> Most companies in the packaging industry provide examples of such product- and market-focused manufacturing organizations. Regional plants that serve geographical mar-

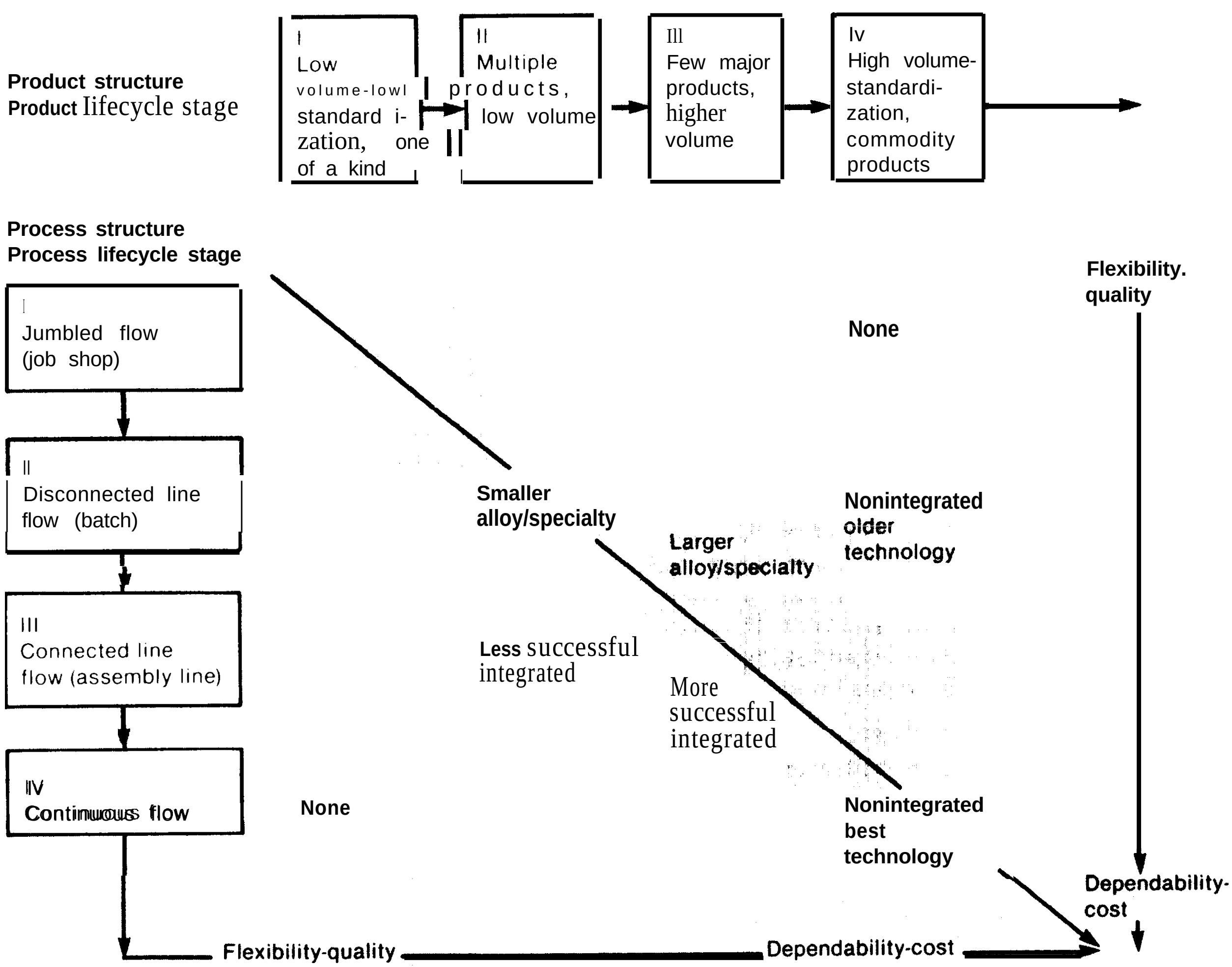
ket areas are setup to reduce transportation costs and provide better response to market requirements.[2]

A hidden assumption in the above analysis, however, as in almost all descriptions of the domestic steel industry, is that there is one, single steel industry. This is not the case: although the largest segment of the industry, the integrated steelmaker, fits the description of process-organized companies, the other two segments far better match the description of companies that have a product or market orientation.

A manufacturing company's products can be characterized along a continuum that ranges from one-at-a-time production to continuous-flow production. For a company to have an optimum, low-cost production system, its stages along these continuums must match. Figure 35 illustrates this idea, using the relative product and process positions of different types of steel companies. The goal is to be on the diagonal of the matrix, so that a company's product stage is consistent with its process stage. The worst cases would be for a

[2]R. H. Hayes and S. C. Wheelwright. "Link Manufacturing and Process Life Cycles," Harvard Business Review, January-February 1979.

Figure 35.—Correlation of Product Lifecycle Stages for Steelmaking Plants



SOURCE: Adapted from R. H. Hayes and S. C. Wheelwright, "Link Manufacture and Process Life Cycles," *Harvard Business Review*, January-February 1979.

company to try to produce a high volume of highly standardized products (product stage IV) with job-shop procedures (process stage I), or for a company with a continuous flow process (stage IV) to attempt to produce a small number of unique products (stage I). As a company or industry evolves, it does not have to move along the diagonal, but it will be more successful if it does.

According to this schematic, the low profitability of many integrated companies can be linked to the fact that they attempt to make too many different products in quantities unsuitably small for the nature of the steelmaking process they use. They do not capitalize on potential scale economies. Integrated steelmaking involves many steps that must be coordinated in order to produce at optimum levels. The economy-of-scale advantage of having a large blast furnace is negated by producing small lots of a great many different finished steel products, because different product types require different finishing equipment. This means investing in highly capital-intensive equipment that will not be fully or continuously used. Thus, unprofitable integrated companies are not appropriately rationalized—their product lines are too various for large-scale production, and the capital investment requirement for each product is too great to be justified by the size of the market for that product. The plant closings of several large domestic integrated steelmaker in the past few years are consistent with those companies' attempts to get back on the product/process diagonal by narrowing the scope of their product lines. Generally, they are halting production of products that are also made by nonintegrated companies or can be imported at competitive prices.

Some integrated companies, however, have the opposite problem: their process stage is too primitive for the high-volume production of a few products. Their production technology does not take advantage of the scale economies that high volume would allow, or their secondary processing is not volume-coordinated with primary processing, or both. The chief process deficiencies for these companies are small blast furnaces and ingot, rather than continuous, casting.

The nonintegrated companies are moving toward expanding their range of products, but in doing so, they more often construct new plants for specific products rather than expand existing plants. In the most efficient mills, there is a very smooth flow of materials for large-volume production of products by a combination of electric furnace steelmaking and continuous casting. The less efficient mills do not have the optimum process for the product stages they are in: the chief problem is the absence of continuous casting in plants that make a relatively narrow range of products; but some plants that do have existing continuous casting equipment produce too many products to allow long, efficient runs.

Alloy/specialty steelmaker vary considerably in their product stages, but generally their process and product stages are properly matched. Some firms produce a large variety of products, while others specialize in a few products made in relatively large quantities. A significant trend is toward expanding mill capacity while maintaining product mix, which permits more continuous processing using new technology. For example, many plants use continuous casters, which permit very rapid changeover to different sizes and shapes of products, and also offer considerable production-cost savings in the form of lower energy consumption and greater yields on expensive, high-alloy raw materials.

Nonintegrated Steelmaker

Fundamental Advantages and the Role of Technology

Nonintegrated carbon steel producers are often referred to as minimills, midimills, cold metal shops, or special-market steel companies. In some analyses, companies OTA classifies as alloy/specialty companies are included in the nonintegrated category. This classification may be correct in terms of the process technology these companies use, but it would not be correct in terms of the products they manufacture.

A few small domestic minimills have been operating since the late 1930's,[3] more than 40 were constructed during the 1960's, and about 10 more were added in the 1970's.[4] The term "minimill" derives from the very small size of the early generation of nonintegrated steelmaker: most made no more than 43,350 tonnes of product a year. Today, a number of plants and companies have capacities in the range of 272,100 to more than 907,000 tonnes (table 97). As a whole, nonintegrated steelmaking capacity and production have tripled in the past decade, and significantly more capacity, probably 0.9 million to 1.8 million tomes, is now in the construction or planning stages.

The nonintegrated companies are generally quite profitable compared to the larger integrated companies. Their success has been based on their use of new technologies and favorable product/market strategies:

. Nonintegrated mills have been quick to adopt promising technological changes: they spearheaded the adoption of electric furnaces, furnace improvements, and continuous casting, all of which contribute to relatively low production costs, low energy consumption, low capital costs, and high productivity. The rate of labor productivity improvement in electric furnace steelmaking has been particularly high: employee-hours per tonne decreased 25.3 percent between 1972 and 1977, compared with 6.9 percent in integrated steelmaking.[5] Further, because electric furnaces use scrap, they consume far less energy than do integrated steelmaking processes: in 1978, integrated plants used an average of 35.2 million Btu to produce a tonne of shipped product, as opposed to 9.9 million Btu for nonintegrated plants producing carbon steels. In recent times the price of scrap has been low relative to the cost of making new iron units from iron ore.
. Plant construction costs and leadtimes are low. The nonintegrated plants can be built for 10 to 20 percent of the cost of a greenfield integrated plant. The elim-

Table 97.—Approximate Plant, Capacity, and Shipment Data for Nonintegrated Mills

Source	Year	Number of plants	Product capacity	Shipment
(1)	1967	34		
(2)	1970	43	4,813,000 +	
(3)	1970			3,706,000
(4)	1972-73	48	5,918,000 +	
(5)	1974	40		2,979,000 +
(6)	1978	52	13,257,000	
(7)				11,291,000

NOTE: Definitions and classifications of nonintegrated carbon steel mills have not been Identical in sources of these data A (+) sign Indicates that figure appears to be based on less mills than those included in OTA system or on an admitted lack of complete data

SOURCES
(l) C L Konir, "The Big Source of 'Mini' Steel Plants." *Iron Age,* November 1967
(2) G J McManus, "Mlnl-Mills Leery of Mldl-Mill Size," Iron *Age,* May 21, 1970
(3) G J McManus, "No More MiniMllls?" Industry *Week,* November 1971
(4) Association. of Iron and Steel Engineers, "Directory of Iron and Steel Plants," 1975
(5) Temple, Barker, and Sloane, "Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry, " July 1977
(6) IIIS *Commentary.* January-February 1979 Assuming 90-percent yield from raw steel capacity
(7) Approximation based on data from AISI.

[3] A. Cockerill ["The Steel Industry: International Comparisons of Industrial Structure and Performance, " Cambridge, 1974) noted that 40 mills were built in the United States during the 1960's. In 1970, 42 plants were noted to be in existence (G. J. McManus, "Mini-Mills Leery of Midi-Mill Size, " Iron Age, May 21, 1970). A 1978 listing includes 53 plants (*IISS* Commentary, January-February 1979).

[4] C. G. Schmidt and R. B. Lelteren, "Mini-Steelplants in the U. S.: Some Technological and Locational Characteristics, " *Land* Economics, vol. 52, No. 4, November 1976.

[5] U. S. Bureau of the Census data.

ination of primary ironmaking and finishing facilities for flat products and complex steel products accounts for much of this difference. The absence of ironmaking and the use of electric furnaces also reduce the amount of pollution abatement equipment needed. The simplicity of nonintegrated plants and the common use of available technology allow relatively quick new-plant construction, usually in 1 to 2 years.

- The product range of nonintegrated plants is narrow, consisting mostly of simple commodity steels in nonflat shapes such as reinforcing bar. Both of these factors permit long production runs with simple equipment.
- Plants serve and draw upon relatively local markets. Plant locations are selected to capitalize on the availability of local ferrous scrap and local labor and to produce for fast-growing local industries, particularly construction companies that use reinforcing bar. Their market strategy is to make special products for special markets, Confining their operations within small, surrounding geographical areas also minimizes transportation, sales, and marketing costs.

As a result of these practices, nonintegrated mills are generally the lowest cost steel producers in the country, and often their products are even priced lower than imports.[6] At the same time, the nonintegrated companies have performed very well for their owners and stockholders, so much so that they have become acquisition targets for other domestic and foreign industries.

The nonintegrated companies are sometimes accused (by integrated producers) of making the "easy," lowest cost and price steel products. But these companies have caused their products to become low-priced by virtue of their low production and capital costs and their well-managed operations. The current trend among integrated companies toward switching to the electric furnace-continuous casting process is surely recognition that the nonintegrated companies have made some wise choices.

The growth of nonintegrated steelmaker in the United States has been matched by similar growth in other countries. A European steel expert has commented on the growth of nonintegrated steelmaking in Europe:

> In recent years a sizable expansion of steelmaking capacity has taken place only in the scrap-based mini-mills. Representative is the 5 Mill, tons capacity of the Bresciani in Italy, who were able to underbid the integrated steelmaker in front of their home doors by a comfortable 50 dollars per ton in non-flat products, This development has been caused by the disregard for the scrap market that was practised for many years by the large integrated steelmaker.
>
> As a result, the integrated steelmaker have continuously lost market share in the non-flat product areas.[7]

Future Changes

New Products

The initial success and growth of nonintegrated steelmaker and of new entrants into the industry have been associated with producing simple products, notably reinforcing bar, but increasingly they are also producing more complex products and higher quality steels. About half of the nonintegrated plants produce only merchant and reinforcing bar, but about one-fifth do not make merchant and reinforcing bar at all.

Many plants make special-quality bars, wire rod, and structural. A few plants make plates, flange beams, I-beams, forging billets, and alloy bars. There is a clear trend toward making these higher grade products. Consider the following comments on one of the newest plants, designed solely for wire rod:

[6] On the west coast, which has the greatest import penetration (40 percent), imports have only 6 percent of the market for reinforcing bar, compared to more than 50 percent for structurals and sheet and strip products (*Iron* Age, July 31, 1978).

[7] W. H. Philipp, "Probable Course of Europe's Steel Industry,'" paper presented at American Institute of Mining, Metallurgical and Petroleum Engineers annual meeting, New Orleans, La., February 1979.

"We will be the only rod mill in North America producing strictly rods," says Thomas Tyrrell, marketing vice-president. "We will have no wire drawing subsidiaries, no rebar line and no potential to shift raw steel to other steel products, when market conditions make them more attractive than rods, '

The concept of isolating markets is not new to Co-Steel, which operates minimills internationally. Raritan River's market is larger than the traditional minimill's, where merchant bars and rebar are typical products, the wire rod will be sold over the entire eastern U.S. and possibly abroad. Another hallmark of the minimill—low investment costs per ton—is common to Raritan, And combining specific markets with efficient steelmaking is the key to minimill's success.

"The whole minimill concept is operational, " says Tyrrell, "since operations are the key to cutting costs. As the theory goes, once you have the product at the lowest possible cost the market comes naturally. Our idea goes one step further, If our operations are the very best, we should be able to command a high price. '[8]

The future strategies of nonintegrated companies have been summarized as "upgrading product mix, concentrating on various shapes or sections that have been abandoned by the major mills and/or specializing in chemistry modifications for selected customers. "[9]

The most important characteristic of most present products is that they are not flat products like sheet and strip. Because conventional rolling equipment for flat products is generally geared for economic production of several million tonnes annually, there is a long-held belief that nonintegrated companies could not move into this product area, and that if they did the change would greatly increase their capital costs. However, this is not necessarily the view within the nonintegrated segment. F. Kenneth Iverson, president of Nucor Corp., has stated that:

Mini-mills started with a relatively simple product—refinforced bar. Now we make plate and wire products, rails, even structural grades. The only thing you can't do with a mini-mill now is make sheet, but even that may not be out of the question in the future. [10]

The minimum optimum scale for flat-rolled products in a nonintegrated plant ranges from 0.5 million tonne/yr for narrow strip to 4.1 million to 4.6 million for very wide strip.'[1] The low end of this range is consistent with larger size nonintegrated plants.

New Small Rolling Mill Equipment

Of greater significance is the current interest in developing new types of flat-rolling equipment for nonintegrated plants: "Voest-Alpine is also developing a flat-rolling mill for wide strip and medium hot strip, capable of production of 250,000 tons to 500,000 tons per year of hot strip at minimum cost."[12] It should be noted that Voest-Alpine is an Austrian firm that sells continuous casting equipment worldwide and is also the owner of a new nonintegrated plant in New Orleans.

The most significant development in small-scale equipment for flat products is the hot reversing mill, which has already entered the marketplace. Sometimes called a Steckel mill, the reversing mill flattens steel by successive, back-and-forth passes through a single stand rather than through many stands, which is the method used in large sheet-rolling mills. The reversing mill eliminates the heat losses that occur when a flat strip travels through a continuous mill. In the reversing mill, the strip travels through the mill and is coiled in a furnace on the other side. Moreover, the simplicity of the reversing mill greatly reduces capital costs and shortens construction times.

A domestic equipment manufacturer has already sold several hot-reversing mills to nonintegrated companies. A Canadian nonintegrated steel producer with 408,150 tonnes of steelmaking capacity will produce steel

[8] *Steelweek*, Apr. 23, 1979.
[9] *World Steel Industry* Data Handbook—U. S., McGraw-Hill, 1979.

"'American *Metal* Market, Dec. 31.1979.
[11] D. G. Tarr, "The Minimum Optional Scale Steel Plant in the Mid-1970' s," manuscript.
"American Metal Market, Aug. 24, 1979.

pipe for a natural gas pipeline with this equipment. The equipment will be used to produce heavy-gauge flat-rolled high-strength steel, one-half-inch thick, in widths up to 72 inches.[13]

The cost of the Steckel mill is reported to be about one-tenth the cost of a conventional large sheet-rolling mill. One domestic nonintegrated producer has been making steel plate in such a mill for a number of years. The following comments by the equipment manufacturer point to the future potential of this equipment for small steel producers:

> In effect, we invented the mini-mill for flat-rolled products.
>
> I question whether any big, 4-million-ton-a-year hot strip mills are ever going to be built again. The steel industry, instead of being all things to all people and looking at a centralized plant for meeting all markets, is now coming to a unit size plant, which might be for a half million ton a year.[14]

An excellent illustration of the potential for small steel companies to apply technology not widely adopted domestically, and thereby to capture a market abandoned by large integrated companies and deeply penetrated by foreign steelmaker, is the case of the Berg Steel Pipe Corp. of Panama City, Fla., which has recently announced the opening of the Nation's largest diameter pipe mill.[15] Heretofore, the United States Steel Corp. was the largest domestic pipe producer with its 48-inch mill; the new plant will make pipe ranging from 20 to 64 inches in diameter, and will be able to produce approximately 181,400 tonnes annually, with an emphasis on pipe for oil and gas transmission and coal slurry pipelines. The use of the pyramid rolling process will be the first domestic application of an established European technology. Its chief advantage over the technology used in domestic mills is that changing production from one pipe size to another can be accomplished in a little over 30 minutes, as opposed to from 8 to 24 hours in conventional mills.

[13] G. J. McManus, "Steckel Mills Reverse Trends in Steelmaking," *Iron Age*, Feb. 4, 1980.
[14] Ibid.
[15] *American Metal Market*, Mar. 18, 1980.

Direct Reduced Iron

It is likely that a decade from now the rather spectacular growth of nonintegrated steel producers will be linked not only to the use of electric furnace steelmaking and continuous casting, but also to the commercial exploitation of DRI.* The introduction of DRI as a supplement to ferrous scrap in electric furnaces will facilitate the manufacture of products. Direct reduction (DR) also provides a means of introducing new iron units of high purity into the steelmaking process, so that electric furnaces can make higher quality steels than they can with scrap. For a number of years, several natural gas DR plants in the United States have supplied DRI for electric furnace steelmaking, and imported DRI is becoming increasingly available.

The advantages and disadvantages of using DRI plus scrap as opposed to using only scrap in electric furnaces are summarized in table 98. There is general agreement within the steelmaking community that the net benefits of using DRI are substantial: both processing and the final steel products can be improved with the use of DRI, and it can lead to actual production cost decreases. Thus far, however, the relatively higher cost of DRI over scrap** and its limited availability have not allowed widespread use.

Economically, scrap costs have been low compared to the cost of DRI, so as long as industry growth could be maintained without going to higher quality products, the use of DRI was not justified. But, as discussed in chapter 7, with further growth of electric furnace steelmaking by both nonintegrated and integrated steel companies, ferrous scrap supplies may not be adequate in the future:

> The increasing problems faced by blast furnaces and BOF's—environmental and high capital costs—have caused a dramatic shift to, and increase in, electric furnace steelmaking. This has and will put an increasing strain on scrap supply and has

*Direct reduction is discussed in ch. 6.
**Presumably with increased R&D and improved DR Processes, the cost of DRI will decrease.

Table 98.—Electric Furnace Use of Direct Reduced Iron: Advantages and Disadvantages Compared to Using All Scrap

Advantages	Disadvantages
1. Higher purity steels can be made even with a relatively large proportion of scrap.	1. Need access to water transportation for DRI imports or capital for DRI plant construction (unless domestic merchant DRI plants are built).
2. Furnace productivity can be increased 10 to 20% because DRI can be continuously fed to furnace.	2. Higher cost than producers using scrap only, if scrap prices are less than DRI cost.
3. Continuous feeding increases useful electrical power 10 to 14%.	3. Unless proportion of DRI in charge is kept relatively low (30 to 40%), nonmetallic impurities can cause increase in energy, time, and fluxing agents.
4. Continuous feeding reduces wasted time 5 to 150/..	4. If bucket charging is used, nonmetallic cause lower productivity.
5. Acoustical noise levels are reduced 10 to 15 dBa.	5 Lack of alloying elements which may be desired requires greater use of alloy additions.
6. Metallic yield is increased.	
7. The variability of product chemistry is reduced.	
8. The cold formability of steels is improved due to lower content of nitrogen and other residuals, and rates of finishing can be increased.	
9. Product surface quality is improved and rejection rates reduced.	
10. There is a smoother, more efficient flow of material from melting to finishing.	
11. Less storage space, plant materials-handling equipment, and inventory are needed.	
12. Lower grade scrap can be used to reduce costs or deal with shortages or price fluctuations for high-quality scrap.	
13. Price fluctuations should be less than for scrap.	

SOURCES R L Reddy, Some Factors Affecting the Value of DRI to the Steelmaker, " AIME Ironmaklng Conference, Detroit, Mlch , March 1979; R A Redard, 'Is the Value of DRI to the Steelmaker Being Properly Assessed?" AIME Ironmaking Conference, Detroit, Mich , March 1979, R L Reddy, "Electric Arc Furnace Steel making With Sponge Iron, " Canadian Mefallurgical *Quarterly, vol.* 1, pp. 1-6, 1979, J W Brown and R L Reddy. "Electric Arc Furnace Steelmaking With Sponge Iron ' *Ironmaking and Steelmaking, No* 1, pp. 24-31, 1979

> brought direct reduction to the fore. Its time has come. Without it, there simply is not enough scrap in the world to support current and projected electric furnace steelmaking.[16]

This increase in demand for scrap, along with higher scrap prices and increasing production of higher quality products, may all combine to make DRI a necessary and economically feasible raw material for nonintegrated producers.

Imports of DRI are becoming more available because a number of large-scale DR plants in natural gas-rich nations are becoming operational, and more are expected within the next decade. A recent analysis and forecast by a domestic steelmaker shows world trade in DRI increasing form 954,000 tonnes in 1979 to 4,350,000 tonnes in 1985.[17] Abundant DRI could act as abundant scrap did during the 1960's to spur the growth of nonintegrated steelmakers.[18] Much of the increased supply of DRI will be coming from Latin America, especially Venezuela and Mexico. It is generally accepted that the often-cited problem in transporting DRI, its potential to heat up and possibly ignite, either has been solved or will be within the near future. The fact is that bulk ocean shipments of DRI have been occurring for the past several years.

In the near future, furthermore, domestic steelmaker will probably have an alternative to imported DRI. Small-scale, coal-based DR plants may become available within the next 5 to 10 years. These reduction plants will need access to coal and iron ore, but they should be particularly attractive to the larger

[16] H. B. Jensen, "New Alternatives for Charge Materials," paper presented at Ferrous Scrap Consumers' Coalition symposium, Atlanta, Ga., February 1980.

[17] Ibid.

[18] "New greenfield direct reduction (DR) capacity is judged to amount to about 18 million tonnes during 1977-83-bringing total DR capacity to about 35 million tonne/yr. However, should scrap prices continue to rise substantially in the years ahead [which would be principally the result of a strong economy in the West), this could attract significant additional DR capacity. If our 'judged doubtful" category were to materialize, another 18 million tonne/yr of DR production capacity would be added by 1983." (World Steel Dynamics, April 1979.]

nonintegrated plants far from large domestic scrap markets. Yet another likelihood is the construction of domestic merchant DR plants. Although these might be coal-based facilities, a natural gas-based plant in Texas has been under discussion for some time. Because most large integrated steel producers are increasing their electric furnace facilities, their increased demand is likely to spur the construction of domestic DR plants.

The rapid rise in foreign electric furnace steelmaking is also leading to increased interest in the use of DRI. For example, it has been reported that Japan has already begun to import DRI from a new plant in Indonesia. 'g The cost of the DRI is approximately $125/tonne including freight, compared to imported ferrous scrap costs of $160 to $170/tonne. A joint industry consortium of 51 Japanese steel mills, with the Ministry of International Trade and Industry, is studying the increased use of DRI. It is clear that DRI will likely become a world trade commodity whose price will be determined by the demands of a multitude of users. Domestically produced DRI might be exported in much the same way that domestic ferrous scrap has been, which means that domestic steelmaker could face problems similar to those with scrap unless they have their own sources of DRI.

Future Expansion Forecast

Integrated steelmaker generally affect a lack of concern about the inroads made by the nonintegrated steel producers, but the financial community has become keenly aware of the growth and future importance of this industry segment at the expense of the integrated companies:

> . . . potential for a considerable restructuring of the domestic industry exists—toward many mini-mills and away from mammoth integrated plants.[20]
>
> Scrap-based steelmaking (will) remain just about the only true growth area in the steel industry (because) they have more modern, more highly automated facilities than the integrated producers and use continuous casting more extensively.[21]

The nonintegrated producers themselves are also expressing a high degree of optimism for the coming decade. One producer has described nonintegrated companies as the new nucleus of a strong-again U.S. steel industry .22 Quantitative forecasts in 1978 showed this industry segment doubling its output in the next decade[23] and increasing its share of domestic steel shipments to at least 25 percent by 1990.[24]

OTA finds these forecasts quite reasonable for two reasons. First, the past growth of the nonintegrated companies has been very high, by approximately 9 million tonnes of shipments during the past decade (see table 97). Second, these companies' record of success, excellent profitability, quick adoption of the best new technologies, and ready access to capital should permit this rate of growth to continue. It is reasonable to believe that these steelmaker could increase output by another g million tonnes of shipments during the 1980's.

Another way to assess the future potential of the nonintegrated companies is to consider what percentage of major types of steel products they will be capable of producing. Table 99 presents OTA estimates, using 1978 data for product mix and assuming that DRI will be used and that some flat products will be made on new types of rolling equipment. The result suggests that nonintegrated companies could potentially double their market share as well, to approximately 57 percent of these products and 25 percent of total domestic shipments of all steel products. These estimates are probably conservative, because the product areas shown are expected to represent an increasing proportion of all steel products and the estimates do not take this into consideration. What is most significant

"American *Metal* Market, Feb. 6, 1980.

[20]J. C. Wyman, quoted in American *Metal* Market, Feb. 5, 1980.

[21]C. A. Bradford, quoted in American *Metal* Market, Feb. 5, 1980.

[22]F. Kenneth Iverson (Nucor Corp.), American *Metal* Market, Feb. 6, 1980.

"Forbes, Dec. 11, 1978,

''Fortune, Feb. 13, 1978.

Table 99.—OTA Estimate of Potential Production for Nonintegrated Steel Companies, 1978 (thousands of tonnes)

	All-industry 1978 production[a]	Technically feasible and potential market for non integrated companies: Percent	Tonnes
Bars (excluding reinforcing)	10,992	**85**	**9,343**
Reinforcing	4,267	**100**	**4,267**
Wire rods	2,316	100	**2,316**
Wire products	2,277	100	**2,277**
Structural shapes (heavy)	4,233	10	424
Plates	7,801	25	1,950
Strip (hot-rolled)	931	25	233
Pipe and tubing	7,031	25	1,758
Total	39,848[b]	57	22,568[c]

[a]From AISI
bRepresents 45 percent of total domestic shipments.
CRepresents 25 percent of total domestic shipments.

about this finding is that for the next decade, most of the anticipated growth in domestic steel production could be accounted for just by growth of nonintegrated steel companies. *

Other than the availability of scrap and DRI, the availability of electricity is the main determinant of the growth of nonintegrated steelmaking. However, an increase of 9 million tonnes of shipments from this segment would lead to an increase in electricity purchases amounting to less than 1 percent of all electricity used by all domestic industry, and less than 0.5 percent of all domestic uses of electricity. ** Such an increase spread over 10 years and a number of locations, many of them in the South and Southwest, is not likely to represent enough additional load on domestic electrical generation companies to warrant special consideration. Nevertheless, unless adequate domestic electricity is available during the next decade, nonintegrated steelmaking could not grow to its full potential, particularly in major industrialized regions. Much depends on current plans and forecasts which will determine whether new electrical generation plants will be constructed.

Also noteworthy is that the analysis of future energy costs given in chapter 5 revealed that under most future energy cost scenarios nonintegrated steelmaker would face more rapidly rising costs than integrated steelmaker. Nonintegrated energy costs would still likely remain below those of the integrated steelmaker because of their lower energy needs, but the difference would be expected to narrow over the next several decades, particularly if these firms adopt DR and become partially integrated.

*This possibility is considered in detail in the projection of capital needs for a modernization and expansion program for the domestic industry presented inch. 10.

**At 605 kWh/tonne of raw steel, a 9. l-million-tonne increase in production would result in an increase in steel industry electricity consumption of 5.5 billion kWh, compared to 1976 total domestic consumption of 257 trillion kWh, 1976 total industrial consumption of 103 trillion kWh, and 1976 steel industry purchase of 44.3 billion kWh, of which about one-third was for electric furnace steelmaking.

Alloy/Specialty Steelmaker

The alloy / specialty segment of the steel industry is difficult to define precisely. In the OTA disaggregation of the industry, companies in the alloy / specialty category are those that make the higher quality and higher priced steel products rather than commodity carbon steels. One recent compilation using this definition lists 33 such companies.[25]

[25]Institute for Iron and Steel Studies, “ Commentary,” January-February 1979.

There is little problem in identifying these companies; the problem lies in measuring their output.

The terms "alloy" and "specialty" do not have precise, generally accepted meanings, The only available data base is from the American Iron and Steel Institute (AISI), which distinguishes four categories of steels: carbon, stainless, tool, and alloy. In the OTA disaggregation, stainless and tool steels are definitely in the alloy/specialty category, but much stainless steel and many materials in the alloy category used by AISI are made by commodity carbon steelmaker (integrated firms for the most part] and to a lesser degree by nonintegrated producers, rather than by alloy/specialty steelmaker. The alloy steels made by the alloy/specialty steelmaker are the higher alloy content, higher priced steels made in smaller quantities. Because these cannot be distinguished, the data for alloy steels other than stainless and tool steels overestimate those alloy steels made almost solely in alloy/specialty steel companies, probably by a factor of five. About half the stainless steel is made by integrated companies. Finally, other types of higher quality, higher priced steels made by the alloy/specialty steelmaker are not alloy at all, but rather variations of carbon steel that are made in small quantities compared to commodity carbon steels; some of these are called "custom made" steels. Examples of these steels include electrical steels, clad plates, thick carbon steel plate, and coated strip. Such steels are included in the carbon steel data of AISI and thus do not enter into OTA data for alloy/specialty companies.

Growth of Domestic Alloy/Specialty Steel Use

The basis for the relative success and growth of the alloy/specialty steelmaker is the increasing use of the steels these companies produce. Data on domestic shipments of alloy/specialty steels for the past decade are given in table 100. Growth in domestic shipments of carbon steels has been quite low—except for 1973 and 1974, domestic shipments remained virtually constant, with a 1.3-percent increase from 1969 to 1978. During this same period, shipments of alloy/specialty steels grew nearly 34 percent. Alloys other than stainless and tool steels had the most growth.

Data on domestic consumption of alloy/specialty steels are given in table 101. The use of

Table 100.—Domestic Shipments of Alloy/Specialty Steels, 1969-78

	Stainless		Tool		Other alloy	
Year	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total
1964	705	0.9	93	0.1	5,863	
1969	825	1.0	103	0.1	7,027	8.3
1970	643	0.8	80	0.1	6,218	7.6
1971	651	0.8	71	0.1	6,291	8.0
1972	775	0.9	82	0.1	6,972	8.4
1973	1,029	1.0	101	0.1	8,400	8.3
1974	1,220	1.2	102	0.1	9,130	9.2
1975	687	0.9	63	0.1	7,589	10.5
1976	924	1.1	69	0.1	7,285	9.0
1977	1,014	1.2	77	0.1	7,869	9.5
1978	1,080	1.2	83	0.1	9,492	10.7
1969-1978 percent change	30.9%		-19.370		35.170	
1979 (1st three quarters)	937	1.3	66	0.1	7,649	10.8

Carbon steel percent change 1969-78 (77,191 -78,172 =) 1.3%

All alloy/specialty percent change 1969-78 (7,955 - 10,655) = 33.9%

SOURCE Office of Technology Assessment.

Table 101.—Domestic Consumption of Alloy/Specialty Steels, 1969-78 (shipments + imports – exports)

	Stainless		Tool		Other alloy	
Year	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total	1,000 tonnes	Percent of total
1964	656	0.8	99	0.1	5,724	7.2
1969	912	1.0	114	0.1	6,811	7.3
1970	727	0.8	94	0.1	5,923	6.7
1971	775	0.8	79	0.1	6,385	6.9
1972	861	0.9	93	0.1	7,207	7.5
1973	1,058	1.0	114	0.1	8,520	7.7
1974	1,255	1.2	118	0.1	9,076	8.4
1975	769	1.0	78	0.1	7,687	9.5
1976	1,016	1.1	89	0.1	7,397	8.1
1977	1,112	1.1	104	0.1	8,163	8.3
1978	1,196	1.1	122	0.1	9,712	9.2
1969-1978 percent change	31.2%		6.3%		42.6%	
1979 (1st three quarters)	994	1.2	107	0.1	7,799	9.7

Carbon steel percent change 1969-78(85,296-94,770) = 11.1%

All alloy/specialty percent change 1969-78(7,836- 11,030)= 40.8%

SOURCE Officeof Technology Assessment

these steels increased about four times more than carbon steels during 1969-78, and since domestic consumption outpaced domestic shipments, it can be concluded that imports captured an increasing fraction of the domestic alloy / specialty market. Imports penetrated the carbon steel market even more, however: domestic consumption of carbon steels from 1969 to 1978 increased by 11 percent, but shipments went up by only 1 percent. Summary data on imports as a percentage of domestic consumption are given in table 102. Imports made their greatest inroads on tool steels and their least on stainless steels. Nearly 8 percent of all alloy / specialty steels used in this country in 1978 was imported; for carbon steels the figure was 19 percent. Except for tool steels, imports of all steels decreased significantly in 1979.

Table102.— Imports as a Percentage of Domestic Consumption, 1969 and 1978

	1969	1978	1969-1978 change	1st three quarters 1979
Stainless	18.1	15.2	– 2.9	11.2
Tool	11.9	35.1	+23.2	40,7
Other alloy	4,5	6.6	+ 2.1	5.7
All alloy/specialty	6.2	7,8	+ 1.6	6.7
Carbon	14.4	19.3	+ 4.9	15.3

SOURCE Offlce of Technology Assessment

The worldwide use of alloy / specialty steels has increased for several reasons:

- advanced technology applications require steels with high-performance characteristics, such as strength and temperature resistance;
- energy conservation has dictated using less steel and more alloy in making automobiles;
- consumers are demanding durables with longer lives and reduced lifecycle costs, built of materials with more corrosion and wear resistance;
- alloy / specialty steels have a comparative cost advantage over other high-performance materials because the others are more energy-intensive in their processing; and
- the economic costs for and sociopolitical problems of minerals extraction are increasing, and this promotes the use of smaller amounts of higher technology steel.

Over the 15-year period from 1964 to 1978, domestic consumption of all alloy / specialty steels grew at an annual rate of 3.6 percent; this was more than double the 1.7-percent growth rate for carbon steel consumption. The growth rate of alloy / specialty steels is likely to increase in the years ahead. Thus, to the degree that imports do not capture an increasing share of the domestic market, domestic alloy/specialty steelmaker should be able to expand at a rate more than double the 1.5 to 2.0 percent per year anticipated for the industry as a whole (see ch. 5).

One factor that OTA has not examined which could limit alloy/specialty steel growth is the problem of shortages of alloying elements, for which the United States is very dependent on foreign sources. This problem has already received considerable analysis elsewhere.[26]

Potential for Exports of Alloy/Specialty Steels

Exports have traditionally played a more important role for alloy/specialty companies than for carbon steel producers. It is generally accepted that domestic alloy/specialty steelmaker are both cost and technology competitive in the world market. One measure of export competitiveness is the ratio of exports to imports; such data are presented in table 103 for the alloy/specialty steels, as well as for carbon steels, for the period 1964-78. Exports of carbon steels have not been large relative to imports, whereas exports of alloy/specialty steels, other than stainless and tool steels, have exceeded imports during 5 years of the 15-year period. A number of generic advantages have contributed to the favorable competitive position of domestic alloy/specialty steelmaker:

- They have a relatively strong technical base and probably a commanding advantage over foreign competitors in product development and secondary processing.
- The United States has relatively low energy prices, an advantage that could increase if DR processes using coal become widely used.
- The United States has a good supply of quality iron ore and ferrous scrap.
- The enormous domestic market, much of it technology-intensive, has encouraged alloy/specialty steel product innovations.
- U.S. labor costs and productivities are competitive with European and possibly with Japanese levels.
- The United States has a very sophisticated industry infrastructure.

These advantages are offset to an extent by the greater level of assistance provided by other governments (particularly in the area of low-cost financing for exports), and by some foreign industries' experience in and infrastructure for export sales and marketing.

[26] See, e.g., *Technical* Options *for* Conservation *of* Metals, Office of Technology Assessment, September 1979.

Table 103.—U.S. Exports as a Percent of Imports

	Carbon	Tool	Stainless	Remaining alloy/specialty	All alloy/specialty
1978	9.3	10.6	36.0	65.6	56.7
1977	9.2	23.1	39.3	40.0	39.0
1976	16.5	21.4	42.3	72.7	62.5
1975	22.4	32.0	45.5	74.5	64.9
1974	34.1	34.6	77.8	115.2	100.5
1973	25.2	31.8	74.2	67.7	67.8
1972	15.4	20.0	42.3	40.2	40.2
1971	14.0	30.8	28.6	74.1	58.8
1970	49.2	11.1	47.5	198.5	141.3
1969	33.8	20.0	47.8	170.4	124.5
1968	11.2	15.4	51.2	43.2	45.3
1967	13,1	10.5	77.2	63.5	66.6
1966	14.4	11.1	65.0	80.4	69.6
1965	21.9	15.4	82.3	173.3	118.9
1964	49.1	22.2	168.4	315.5	225.8

SOURCE American Iron and Steel Institute

Nevertheless, one major domestic producer (Armco) has demonstrated that aggressive marketing can improve exports. In 1978, it exported 4.6 percent of its specialty steel, compared to 2.9 percent in 1977.[27] This export market change was the largest for any domestic steel area, and is even more impressive when the depressed worldwide demand for steel in 1978 is considered. Most foreign steel industries operated at low rates in 1978 and were unprofitable (see ch. 4), but domestic alloy/specialty producers were quite profitable. Another major domestic producer has reported that it regularly exports 10 percent of its production.[28]

The growing worldwide demand for alloy/specialty steels has not gone unnoticed by foreign steelmaker, and foreign alloy/specialty steelmaking capacity has been increasing. Data for the Japanese steel industry for 1965-77 are given in table 104. Japanese growth in alloy/specialty steels has been great, nearly a fourfold increase in production and exports in the 12-year period. This is roughly twice the rate of growth for Japanese carbon steel production and exports. Alloy/specialty steels imports have made less penetration into the Japanese market than have carbon steel imports, by about half. Japan is the single largest supplier in the world export markets for both carbon and alloy/specialty steels, and, except for some very narrowly defined alloy/specialty steels made by other nations, it is the United States' major competitor in those markets.

Stainless steels represent the single largest type of alloy/specialty steel in production and in world trade, and they are also subject to the most price competition. The Japanese and European shares of this market totaled 82 percent in 1976. In 1976, 47 percent of Sweden's stainless production and 39 percent of Japan's were exported, and the British Steel Corp. has planned to double its capacity and export 40 to 45 percent of its stainless. It is difficult to believe, however, that either Great Britain or Sweden can be more competitive than domestic producers in a fair market. It must be recognized, however, that there is now considerable excess worldwide capacity, which will make effective imple-

[27] Armco, *1978 Annual Report*; presumably the exports consisted mostly of electrical and stainless steels.

[28] R. P. Simmons, president, Allegheny Ludlum Steel Corp., testimony before the Senate Banking, Housing, and Urban Affairs Committee. Nov. 19, 1979; presumably the exports consisted mostly of stainless steel.

Table 104.—Japanese Production and Export of Alloy/Specialty and Carbon Steels, 1965-77

	1965	1977	1977/1965
Alloy/specialty steel production (1,000 tonnes)			
Stainless	396	1,626	
Tool	110	207	
Other alloy/specialty	1,363	5,650	
Total,	1,869	7,483	
All alloy/specialty			
As percent of total production	4.7 "/o	8.4%	79%
Production tonnage change 1965 -77			387
Exports as percent production of total	14.3	18.4	29
Percent exports to United States	NA	19.2	
Change in export tonnage 1965 -77			420
Change in import tonnage 1965-77			78
Carbon steels			
Change in production tonnage 1965 -77			165
Exports as percent of total production	27.6	38.6	40
Percent exports to United States	NA	20.7	
Change in export tonnage 1965-77			272
Change in import tonnage 1965 -77.			184

NA = not available

SOURCE Japan's Iron & Steel Industry 1978 Kawata, Tokyo. 1978 mentation of the new Multilateral Trade Agreement (see ch. 4) difficult. Nevertheless, the worldwide rate of growth for stainless demand (about 5 percent per year since 1964) should stay close to the 5.8-percent annual growth rate in foreign capacity, which has held since 1970. If the United States is to increase its stainless exports, then it must do so by making inroads on present foreign market shares, especially those of Europe and Japan.

Technological Improvements in Alloy and Specialty Steel making

The alloy/specialty steel companies have modernized considerably during the past several years, but even before this period they were more technology- and research-oriented than the rest of the domestic steel industry (see ch. 9). The increase in yield from raw to finished steel (see table 105) is partly a result of improving technology, primarily from increased use of electric furnaces (see table 106), continuous casting, and other relatively new steelmaking technologies. The yield for alloy/specialty steels remains lower than for carbon steels, however, because alloy/specialty steels are made in much smaller lots.

The role of technology in the future of alloy/specialty steelmaker will likely remain important. This industry segment spends considerable funds on R&D (see ch. 9), and it is likely to continue to develop and adopt new process and product innovations. The use of powder metallurgy fabrication has already begun to increase. Most significant is the larger potential of powder rolling technology, which is an energy- and materials-efficient way to produce sheet and strip products. Usually prealloyed powder is made from molten alloys. The powder is then rolled, cold or hot, and consolidated into a high-density, coherent metal. The process facilitates the production of very highly alloyed materials, which present problems in casting and which have limited plasticity for normal rolling of ingots into sheet and strip.

Another future development is the plasma arc melting furnace, a variation of the conventional electric arc furnace, which is just now being proven commercially. It appears to offer great efficiencies, and it may also facilitate the recycling of high-alloy-content waste materials. Chapter 9 provides greater detail on the past adoption of other important new technologies, such as continuous casting and argon oxygen decarburization, by alloy/specialty steelmaker.

Table 105.—Percentage of Domestic Yields, 1969 and 1978 (shipments/raw steel)

	1969	1978	Change
All alloy/specialty	53.4	58.4	+ 5.0
Stainless	58.0	61.0	+ 3.0
Alloy (including tool).	52.9	58.1	+ 5.2
Carbon	68.2	73.7	+ 5.5

SOURCE Off Ice of Technology Assessment

Table 106.—Percentage of Raw Steel Made in Electric Furnaces, 1969 and 1978

	1969	1978	Change
Stainless	100	100	0
Alloy (including tool).	34.9	41.0	+ 6.1
Carbon	10.7	19.5	+ 8.8

SOURCE Office of Technology Assessment

Integrated Steelmaker

The future prospects for the nonintegrated and alloy/specialty producers appear quite favorable. Nonintegrated producers may undergo a 100-percent growth during the next decade, and alloy/specialty producers are likely to expand by about a third. In contrast, the growth of the integrated steelmaker will likely be small, perhaps 10 to 20 percent during the next decade, depending on the rate of growth of carbon steel consumption and the extent of imports. In addition to the shift of carbon steel production to the nonintegrated producers and the trend toward more use of alloy/specialty steels, the integrated segment of the industry has experienced the following structural changes during the past decade:

- There has been a shift in the raw materials used, primarily from original domestic sources of iron ores to the lower grade taconite ores and imported ores,
- Markets have shifted from the Northeast and North Central States to the South and West.
- Concern about heavily concentrated sources of pollution is increasing.
- There are greater oscillations in market demand and levels of profitability.
- Old plants are gradually deteriorating.
- Significant changes in the technology of steelmaking require a fundamentally new plant layout to achieve maximum efficiency.

These changes, which increase costs and the need for modernization, are continuing to contribute to the loss of market share by the integrated companies. Moreover, the ratio of capital investment to profitability for the integrated companies is the highest of the three segments. It is conceivable that by 1990 the products of integrated steelmaker will account for just over 70 percent of domestic steel shipments, compared to 85 percent in 1978. This does not necessarily imply that integrated plants will close—a very low rate of growth relative to the other industry segments may account for much of this market loss. However, it also does not imply that plants will not close. A number of smaller and older integrated plants would require very large sums to rejuvenate technologically, sums too large to be justified on strictly economic grounds.