INTRODUCTION

Although continuous casting was conceived and patented in 1865 by Sir Henry Bessemer, one of the original founders of modern steelmaking, it was many years until its engineering and equipment problems were solved and the process commercialized. In the early 1960's significant amounts of steel began to be continuously cast in a number of the world's steel industries. Today continuous casting is the preferred choice in new steelmaking plants, although there are still some types of steel which have not been converted from the older ingot casting method to continuous casting. This analysis will examine the costs and benefits of implementing more continuous casting in the United States, as well as its potential for helping to solve many of the problems confronting the domestic steel industry.

WHAT IS CONTINUOUS CASTING?

To appreciate fully the substantial benefits of continuous casting it is necessary to review some aspects of modern steelmaking and the older process of ingot casting. In both processes, molten steel (usually called a "heat") is prepared in an oxygen furnace, an open-hearth furnace or an electric furnace. The molten steel is next transferred in a ladle to either a nearby ingot or continuous casting facility. Various types of ingots are prepared, in both processes, depending on the size and shape of the final steel products to be manufactured. Three types of ingots are made: billets, blooms and slabs (see Figure 1.) Slabs are used to make plate and other flat products. Billets and blooms are used to make structural shapes, round products and tubes. In traditional ingot casting, billets are often made from blooms by a rolling operation.

In ingot casting a heat of molten steel is poured into one or more relatively large rectangular molds. After solidification of the steel the ingot molds are mechanically “stripped” or pulled away from the ingot. In the next step the ingots are placed in tightly covered soaking pits. The pits are heated in order to raise the temperature of the ingot. The ingots are then rolled to the desired shape in a primary rolling mill. Relatively long times may be required in the soaking pits to achieve the correct uniform temperature throughout the ingot. The total time required, from ingot casting to rolling of the semi-finished shape (slab, bloom or billet) can be seven or more hours.

The continuous casting process replaces these separate steps of ingot casting, mold stripping, heating in soaking pits and primary rolling with one operation. In some cases, continuous casting also replaces reheating and rerolling steps. An example of a typical continuous casting apparatus is shown in Figure 2. The basic concept in continuous casting is the use of an open ended mold to cast an indefinite length of the desired cross-sectional shape. The molten steel solidifies from the outer cooled surfaces inward during the casting process, so that finally a fully solid slab, bloom or billet is produced which can then either be processed in a secondary rolling mill or shipped as a semi-finished steel product. While there are many designs of continuous casting machines, the basic feature of all is their one-step nature: liquid steel is continuously converted into semi-finished, solid steel shapes. Clearly, long production runs of a particular product are made easier and more efficient with continuous casting.

THE BENEFITS OF CONTINUOUS CASTING

The main benefits of continuous casting over ingot casting are discussed in the following pages:

- o considerable energy savings
- 0 less scrap produced, i.e. improved yield
- 0 improved labor productivity
- 0 improved quality of steel
- 0 reduced pollution
- 0 reduced capital costs
- 0 increased use of purchased scrap when output is maximized.

Energy Savings and Increased Yield The continuous casting process saves energy directly through the elimination of energy intensive steps and indirectly through increased yield. The elimination of soaking pits, reheating furnaces and primary rolling mills reduces the consumption of fuels (natural gas, oil and in-plant by-product gases) and electricity. This energy saving is approximately one million BTU's per ton cast. In Japan, where one half of all steel is produced by the continuous casting process, the direct energy saving is apparently about 50% of that used in traditional ingot casting.

Energy is also saved by the substantial increase in yield attained by the continuous casting process. Yields are increased by at least 10 to 12%, and 15 to 20% in some cases. The increase in yield comes from reduction in scrap generation. End losses, a natural consequence of treating individual ingots, are eliminated and oxidation losses are reduced because of reduced exposure of hot steel to air. In addition, the simplicity and better control of the continuous casting process leads naturally to improved overall efficiency. Increase in yield means that more shipped steel can be obtained with a given amount of molten steel. For example, if the yield increase is 10%, then for 10 tons of molten steel one additional ton of shipped steel results. All the energy normally used to product this "extra" ton of steel has been saved, including mining of ores and converting coal to coke. The average energy saving because of increased yield amounts to about two million BTU's per ton continuously cast. The sum of direct and indirect energy saving is thus three million BTU's per ton cast, corresponding to a significant cost saving.

These energy savings are averages of many types of steels. Actual savings may differ considerably from case to case. However, the energy savings reported above are probably conservative. For example, one detailed analysis showed a saving of 5.5 million BTU's per ton cast for the traditional integrated steelmaking route of blast furnace (to make iron) and basic oxygen furnace (to make steel), and 2.6 million BTU's for the route used by non-integrated mills of scrap fed electric furnaces.[1)] It is probably safe to say that the total energy savings because of continuous casting is normally equal to about 10% of the total energy used to make finished steel products.

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1) This analysis assumes an increase in yield of 10%, which is probably conservative; this will be discussed at greater length at a later point. The analysis was by J. E. Elliott, in The Steel Industry And the Energy Crisis, J. Szekely, cd., Marcel Dekker, N.Y., 1975, pp. 9-33.

It should also be noted that a comprehensive NATO study and survey of steel industry experts throughout the world, which considered 41 energy-conserving measures for steelmaking, concluded that continuous casting had the best combination of potential for energy conservation and return on investment.[1)]

Improved Labor Productivity The increase in labor productivity with continuous casting results from elimination of the many steps of ingot casting, all of which demand direct labor input. The U.S. Department of Labor reports that 10 to 15% less labor is required for continuous casting.[2)] Increase in productivity also results from the increase in yield and greater tonnage of shipped steel, improved working conditions and from reduction in production time from seven or more hours to one to two hours from pouring of molten steel to production of semi-finished forms. Advances have recently been made in eliminating time losses when products of different size or composition must be made sequentially,

Improved Quality of Steel Most industry personnel report an improvement in quality of some continuously cast steels. The reduced number of steps and greater automatic control of the process both lead to fewer defects in the steel. There have been steady improvements in the process, particularly in the production of slabs for flat products requiring high surface quality.

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1) NATO/CCMS-47, 1977, The Steel Industry.

2) U.S. Department of Labor, BLS Bulletin 1856, 1975, p. 4.

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Reduced Pollution It is generally recognized that continuous casting reduces pollution. The soaking pits and reheating furnaces are eliminated; less energy is required; reduced energy requirements leads, to less pollution produced. Hot steel is exposed to the atmosphere for a shorter time, producing fewer airborne particulate. The yield is increased which means that less primary steelmaking is required for agreater level of shipped steel. This means less coke manufacture in integrated plants using blast furnaces; coking is the largest source of pollution in steelmaking, particularly of toxic substances.

Reduced Capital Costs Although it is difficult to substantiate a reduction in capital costs with actual cost figures, it is generally agreed that capital costs are reduced because of the elimination of molds and stripping equipment, soaking pits, reheating furnaces and primary rolling mills. A study by Resources for the Future of five new steel technologies concluded that continuous casting had the greatest potential for cost saving. Their assumption of no technological limitations is more true today than in 1976.[1)] Their model recommended the adoption of continuous casting for both new facility capacity expansion and substitution of existing ingot casting.

Increased Use of Purchased Scrap If it is assumed that the increase in yield is taken advantage of by maintaining molten steel production, and that adequate downstream facilities are available for processing of the

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[1)] The other four technologies were: scrap preheating, direct reduction based on natural gas, coal gasification for direct reduction and cryogenic shredding of automobile derived scrap. W. Vaughan et al., Government Policies and the Adoption of Innovations in the Integrated Iron and Steel Industry, 1976.

semi–finished forms, then more purchased scrap is required. Increased yield causes less in-plant scrap to be produced, Normally this “home” scrap would be recycled back to the steelmaking furnace or blast furnace, or both. In order to maintain plant liquid iron to scrap ratios, purchased scrap must replace the lost home scrap (see Appendix A).

U.S. AND FOREIGN RATES OF ADOPTION OF CONTINUOUS CASTING

To understand the potential of continuous casting to modernize the domestic steel industry and improve the U.S. competitive position in steel, it is instructive to consider the extent to which continuous casting has been adopted in other countries. The disturbing fact is that the U.S. has fallen behind almost all the steel industries of the world in adoption of continuous casting. For example, in 1978 Japan reached a level of use of 50%, that is, 50% of the first steel made in a basic oxygen, open–hearth or electric furnace (“raw” or “crude” steel) was continuously cast. The European Community in 1978 continuously cast 29% of its steel. However, in 1978 the U.S. was at a level of only 14% use of this beneficial technology.

Summary data on the percent adoption levels of continuous casting for several nations are given in Figure 3 and Table I. More complete data for a greater number of nations, in terms of actual tonnage as well as percent usage, are given in Table 11.

The data reveal that the U.S. has a very low level of continuous casting. The only major foreign steel industry with a lower level of continuous casting than the U.S. is the Soviet Union’s, and that is explained by their unusual commitment to the open-hearth process which does not readily interface with continuous casting equipment. The energy-intensiveness of the Soviet iron and steel industry is suggested by its 13% share of total energy consumption, compared to about 3% for the Us., and must be considered a consequence, in part, of their low use of continuous casting.

The high rate of adoption of continuous casting by many countries, particularly the Japanese, is explained by the considerable expansion of their steel industries in the late 1960's and early 1970's. When new steel plants are constructed there is little choice but to select continuous casting. Its benefits are compelling. More recent construction of steel plants in third world nations has also revealed the unequivocal advantages of continuous casting.

The most important factor explaining the low rate of U.S. adoption of continuous casting is the low rate of construction of new steel plants during the past several decades. It is true that the substantial number of new small, non-integrated steel plants using scrap fed electric furnaces ("mini-mills") built in the U.S. after World War II usually process all their steel by continuous casting. However, this segment of the industry represents only about 12% of domestic tonnage.

The main issue confronting the domestic steel industry with regard to greater adoption of continuous casting is: <u>can replacement of existing ingot casting facilities with continuous casting be justified economically.</u> Although one integrated steel company, McLouth, replaced all its ingot casting with continuous casting, and another, National Steel, has embarked on such a course (by late 1980 it will process 40% of its steel in this manner), most of the large integrated domestic steel companies have not pursued this strategy. However, just recently CF&I Steel Corporation has announced its intention to increase from 18% to 100% its use of continuous casting by replacement of its ingot facilities.

The domestic steel industry has resisted using its limited amount of discretionary capital for investments in continuous casting. It has instead used its capital for several alternative types of investment: (1) The industry has become increasingly focused on short-range capital projects with payback periods of one to two years. Capital is used to finance incremental technological improvements which minimize capital expenditures as well as the time necessary for implementation. (2) There are other major capital projects that offer a greater return on investment than continuous casting in older integrated plants which have lagged the industry in modernizing. For example, old open-hearth steelmaking furnaces are still being replaced by either basic oxygen or electric steelmaking furnaces. (3) The industry has used capital to repair or replace worn out equipment. (4) There have also been some major diversions of capital out of steelmaking. This is generally justified by the industry on the basis of the poor profitability of the steel business or the need to compensate for the cyclic nature of the steel business. (5) The industry has claimed that much of their capital must be spent for equipment to meet state and federal environmental and worker health and safety regulations.

Other reasons cited by the U.S. steel industry for not replacing more ingot casting with continuous casting are: (1) the difficulty of justifying replacement of operational ingot casting facilities that have not been fully depreciated; (2) costs and difficulties of substantially modifying an operating plant; (3) additional capital requirements for downstream facilities to process increased semi-finished steel production; (4) technical problems with some types of steels and, in some cases, relatively small production runs; (5) difficulties in expediting EPA permits, and costs of modifying other facilities which EPA may demand before granting construction permits for continuous casting; and (6) uncertainties surrounding the degree of competition that may result from imported steel.

Any examination of the degree of adoption of new technologies by the domestic steel industry inevitably brings comparisons with the Japanese steel industry which is generally accepted to be the most modern and efficient in the world. Moreover, much of the steel imported into this country is from Japan (approximately 30% in 1978) and Japan has an extremely large fraction of the world steel export market (about 25% to 30% in recent years). During the past several years the Japanese have maintained a steady stream of public announcements concerning their continued high adoption of continuous casting and its importance in explaining their very successful campaign to reduce energy consumption in steelmaking and increase the yield of their steelmaking operations. Their success is indicated by the absence of price increases during the past two years even though their energy costs have soared (however, profit levels have decreased, see below).

Although much of the increased use of continuous casting by the Japanese has been related to their steel industry expansion, in more recent years they have also pursued a replacement strategy. Their goal of 70% production using continuous casting within a few years will probably be met. This increase is even more remarkable in view of a number of negative factors facing their industry; these factors include low rates of capacity utilization (about 70% compared to 85 to over 90% for the U.S. industry); the closing of many older facilities; continued loss of world export markets; and very low profit levels. The main reason why these adverse factors have not impeded greater continuous casting adoption is the channeling of capital at very favorable interest rates to the Japanese steel industry by the complex Japanese government and banking system.

POTENTIAL LEVEL OF ADOPTION FOR THE U.S.

Although the data of Figure 3 and Table I and II clearly show the relatively low level of continuous casting usage in the U.S., the real issue is: how much continuous casting could and should be adopted by the domestic steel industry, and in what time frame?

There can, of course, be no simple calculation performed to determine unequivocally how much continuous casting the domestic steel industry should use. At best we can examine the feasibility of several possibilities. First, we believe it appropriate to set the time frame. Considering the large size of the domestic industry, the long lead times for construction, the problems of capital availability and the possible need for federal assistance which would require extensive Congressional deliberation, 1990 is a realistic goal for substantial expansion of domestic continuous casting capacity.

With regard to the level of continuous casting to aim for, it it appears that levels of from 25% to 50% are feasible and that 50% is necessary to achieve even minimum competitiveness on the international market. The 25% level has been suggested in several recent analyses of the steel industry. However this level reflects nothing more than extrapolation of the past adoption rate for the industry to about 1990.

Even attaining this modest goal could be frustrated by a continued "cost-price squeeze" and substantial capital shortfalls, resulting from increasing production costs and government limits on prices.

Although it is not possible to examine fully in this analysis the economic health of the domestic steel industry, it should be appreciated that the industry has been experiencing severe economic problems. For example, the industry capacity has been falling; in the past two years there has been a loss of two million tons or 1.5% of total raw steel capacity per year. Because of low, but steady, increases in domestic consumption of steel, this has led to increasing dependence on foreign imports. In the past two years imports have accounted for 18% of domestic consumption, and if imported steel in the form of finished non-steel products, such as automobiles, is considered, then imports are even higher. As a consequence, the U.S. is the only major industrialized nation dependent on steel imports, since for the past two years the domestic steel industry has operated at virtually full capacity.

Much of the imported steel has been traded at artificially low prices. This situation stems from the fact that many foreign steel industries are directly or indirectly state owned, notably the British, French and Italian who accounted for 3.2%, 8.3% and 3.7% of our imports in 1978. Hence, when the world steel market is depressed, as it has been in recent years, these steel industries can be used to accomplish national objectives such as maintaining employment rather than making reasonable profits from steel sales.[1)] As a result, relatively low priced imports

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1) "At present export price levels, exporting is losing the West's steel producers about $4 billion per year!" World Steel Dynamics, Peter F. Marcus and Karlis M. Kirsis, September, 1979.

hold domestic prices at levels which prevent accumulation of enough capital to modernize or expand the industry.

Although imports are certainly not the sole cause of obsolete facilities, it is generally accepted that the domestic steel industry has one of the world's highest proportions of obsolete facilities, probably in the order of 20 to 25%. One major indication of the modernity and competitiveness of a steel industry is the national yield (shipped steel tonnage divided by raw steel tonnage). For 1978 the U.S. yield was 71.5%, while the Japanese yield was 89.4%. One of the chief determinants of the yield is the amount of continuous casting employed.[1)] Calculations have shown that if the continuous casting usage was increased to 25% for the U.S. the yield would probably increase to 74%. This would be considered a significant improvement and difficult, or impossible to achieve by any other means, other than by constructing totally new steel plants. Yet if this 25% level were achieved by 1990, the U.S. would still be behind most of the world's steel industries.

A 50% level of adoption is physically achievable in the U.S. by 1990; that is, there are no engineering or technological reasons why this level could not be attained. OTA calculations have shown that at this level of adoption the national yield could be increased to at least 76%.[2)]
The 50% goal can be supported by the following factors:

[1)] Even at comparable rates of continuous casting usage the Japanese steel industry would have a higher yield (expressed as the ratio of shipped steel to raw steel) than the U.S. industry for several reasons, including: a generally more modern and newer physical plant; the shipment of steel which undergoes substantial finishing by customers; and a product mix which include less sheet steel than the U.S.

[2)] This yield of 76% may appear to be lower, especially relative to that of the Japanese, as noted previously; but we have not assumed any large scale closing of older U.S. steel plants which would increase the base yield for the industry at the expense of a capacity loss.

- in 1974 when the domestic industry was doing exceptionally well a forecast made by A. D. Little on the basis of a survey of industry personnel concluded that by 1985 there would be a 53% usage of continuous casting;
- the Japanese and U.S. steel industries are similar enough in product mix and size to suggest that if the Japanese can produce 50% and probably 70% of their steel by continuous casting, then a level of 50% for the U.S. industry is technically feasible;
- in a survey conducted by OTA of steel industry personnel this past year on future technological changes the respondents projected a U.S. level of 54% adoption by 1990 and 74% by 2005;
- if appropriate federal policies were designed to stimulate greater conversion to continuous casting, by providing some means of obtaining the necessary capital, then it would be economically feasible to obtain the 50% usage level (greater details on costs will be given in the next section).

One top executive for a major steel company who has provided much useful information to the OTA assessment has suggested feasible targets of 50% for 1987 and 70% for 1990. Similarly, one long time steel industry analyst on Wall Street has just suggested that "the U.S. could get to 40 percent by 1985 if the money was available."[1)]

[1)] Charles Bradford of Merrill Lynch, Pierce, Fenner and Smith, in an interview in SteelWeek, September 24, 1979.

ECONOMIC COSTS AND BENEFITS

The economic justification for replacing existing ingot casting facilities with continuous casting will now be examined. There are two key areas to be discussed and quantified before proceeding to a calculation of return on investment; these areas are: the significance of the increase in yield with regard to new steelmaking capacity, and the direct production costs savings provided by continuous casting.

Increased Capacity What has not been fully appreciated by some steel industry and policy analysts is that continuous casting is a most economical way to increase steelmaking capacity of existing plants for the U.S. In the U.S., building new major integrated facilities appears impossible under existing or projected economic conditions, and new mini-mills will still represent relatively small tonnages. The substantial increase in yield from raw steel to semi-finished steel associated with continuous casting means that more steel can be shipped from a given amount of molten steel. As noted earlier, although that increase in yield will be plant and product specific, it is probably 10% to 12% for most cases and may go as high as 15% to 20% in some situations.

In view of the large degree of equipment obsolescence, industry contraction and steadily increasing domestic steel consumption, the benefits to be gained from an economical way to increase the capacity of existing plants are considerable, including the avoidance of increased dependence on imports. Past experience such as in 1974 has shown that once dependence on imports occurs and when the world supply of steel becomes tight, the price of historically cheap imports escalates sharply and becomes a significant inflationary factor in the domestic economy. ational security is also affected, since it can be difficult to obtain required steel. Virtually all current analyses point to considerable shortfalls in capital for the domestic steel industry, a growing demand for steel in the years ahead and a very tight world supply of steel by the mid to late 1980's. Factors promoting the latter include: continued contraction of Western European steel industries, insufficient new capacity in third world countries to meet their rapidly increasing demand, and likely insufficient domestic capacity in Soviet bloc nations and the People's Republic of China.[1)]

Although increased capacity because of improvement in yield is a direct benefit of continuous casting, there is another "hidden" cost to be considered. This arises from the costs of purchasing scrap metal to substitute for scrap not generated by the continuous casting process. In considering this factor we will make the following two assumptions: 1) liquid steel production remains constant; 2) adequate downstream processing facilities for handling of the continuously cast semi-finished steel is present or is put in place.

The profit of the additional shipped tonnage is determined by the ratio of the cost of the liquid steel to that of the purchased scrap. The lower the cost of purchased scrap relative to in-plant costs to produce the liquid steel, the greater the profit from the increase in yield and capacity. This ratio is difficult to determine, varies with time and is very plant specific. Since most liquid steel costs are associated with

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[1)] See for example, CIA Reports: World Steel Market-Continued Trouble Ahead, May, 1977; China; the Steel Industry in the 1970's and 1990's, May, 1979; and The Burgeoning LDC Steel Industry: More Problems For Major Steel Producers, July, 1979.

molten iron produced in blast furnaces owned by the steel company itself, there is very little available information on the proper internal cost of such “hot metal”. From many discussions with steel industry personnel it has been determined that the cost of hot metal is typically in the range of $120 to $180 per ton. Factors determining the cost include: the age of equipment, the general efficiency of the plant operation, capacity utilization, size of the blast furnaces, and whether or not the company owns the sources of its raw materials. Although the price of scrap varies considerably over time, it has generally been somewhat less than $100 per ton. Another factor to consider is the normal operating profit on steel shipments which would accrue to the additional steel shipments from the increase in yield; this operating profit is typically $25 to $50 per ton. Because of the wide variations in all cost and profit figures among companies and among plants of any one company, and because we wish to make conservative estimates of returns on investments we have used the three levels of $25, $50, and $75 per ton benefit for additional steel shipments due to the greater yield of continuous casting. In addition, we will assume two levels for the increase in yield: 10% and 12%.

Reduced Production Costs Before proceeding to the return on investment calculation however, an additional profit factor must be considered: the reduction in production costs for all the steel continuously cast. The primary cause of reduced production cost is the decrease in energy consumption which we have already described, It is noteworthy that ten years ago energy was approximately 10% of steelmaking costs. Today it is over 20%. Because the price of energy and hence its contribution to the costs of steelmaking appears destined to rise the future importance of continuous casting as a cost reduction tool will increase. Other nations, more sensitive to energy costs in the past than the U.S., particularly Japan, have placed great emphasis on this benefit of continuous casting. Because about one-third of the energy saving from continuous casting for the domestic steel industry is accounted for by reduced use of purchased electricity and fuels, such as natural gas and oil, and the other two-thirds derived from in-plant energy by-products could be put to other productive uses, the U.S. steel industry must also turn to continuous casting or face a decline in its competitive posture.

From many discussions with industry personnel the total reduction in production costs resulting from reduced energy use, improved labor productivity and reduced environmental costs amounts to approximately $10 per ton cast for a typical plant.

Return on Investment The results of a complete set of calculations for the return on investment for substitution of continuous casting for ingot casting in existing integrated plants are given in Table III. Three levels of capital costs have been used: $40, $60 and $80 per annual ton capacity for the casting equipment. These have been chosen on the basis of limited published data and extensive discussions with industry personnel. Even with what we believe to be relatively conservative assumptions, the economic rewards are substantial, with a return on investment of over 20% likely. At the 50% level of continuous casting usage an industry yield of at least 76% could be attained. Again it should be noted that both return on investment and yield will be plant specific.

Assumed Growth in Raw Steel Production The calculations performed above have assumed raw steel production remaining static at the 1978 level. If we assume that domestic shipments could increase by 2% per year from 1978 to 1990, then 26.3 million more tons must be supplied. Of this, 5.9 million tons can be accounted for by the attainment of 50% continuous casting on the 1978 base, leaving 20.4 million tons to be supplied by additional raw steel capacity. If we assume that, at the margin, 75% of this additional capacity will be made by continuous casting and a total steelmaking yield of 80% compared to 70% for the remainder, then 26.5 million tons of raw steel capacity must be added. The net result would then be that 54% of all the raw steel produced would be continuously cast. It should be emphasized, however, that an increase in continuous casting will substantially reduce the amount of new raw steelmaking capacity which must be added under conditions of growth. Hence, total capital needs for the industry would be much lower than would be calculated on the basis of simply adding new steelmaking capacity. The 2% per year growth figure could be criticized as too optimistic. However, if we note that there would also be a continuation of capacity reduction due to obsolete facilities being closed, requiring perhaps a 1% per year level of replacement, then this calculation is not unreasonable for the time period used.

ISSUES FACING CONGRESS

The major issue for Congress to consider is whether the domestic steel industry will be able to increase its proportion of continuous casting to near the 50% level, the level needed for competitive parity with steel industries of other countries. If our steel industry does reach the 50% level of continuous casting, the energy savings for the nation will be substantial, amounting to the equivalent of 25 million barrels of oil per year less than consumed in 1978.

To help put this issue in perspective it is also necessary to understand another dimension of the domestic steel industry's economic problems: the cyclical nature of the industry. This can be demonstrated by a great many types of economic and financial data. To illustrate this cyclic phenomenon as well as the comparatively poor economic performance of the domestic steel industry relative to other American manufacturing industries, data from 1950 to 1978 on industry profits as a percent of stockholders' equity are given in Table IV for the domestic primary iron and steel industry together with averages for all domestic manufacturing industries. In recent years the periodicity of the peak-to-trough steel business cycle has been four years.

From these data, we see that 1979 will likely be a peak year. If sufficient modernization of the industry does not take place during the next decade, then by the next surge in steel demand in the late 1980's the industry will be severely lacking in competitive capacity. This period may also coincide with a worldwide shortage of steel capacity and high world demand. Thus, the nation could be especially vulnerable to high priced and scarce steel imports.

The greater adoption of continuous casting by the domestic steel industry cannot be considered a radical change or innovation.

It should be viewed as a near term technological fix, of particular significance to the older, large integrated steel plants. But it is neither a final nor a complete fix for the industry. At the very best, the use of significantly more continuous casting will keep the industry viable over the next decade. Ultimately more dramatic technological improvements are needed to greatly reduce energy and other production costs. There are distinct possibilities, but the analysis is beyond the scope of the present paper. The final OTA steel industry assessment report will examine advanced technologies.

It is also not feasible in this brief technical paper to review all the current government policies affecting the steel industry or the array of potential government actions which could assist the industry to improve its technological and economic performance. On strictly technical and economic grounds, however, we believe the present analysis offers compelling reasons for the domestic steel industry to adopt more continuous casting. As the steel industry begins in late 1979 and 1980 to experience the down part of its business cycle, there will be great pressure put on Congress to provide assitance in order to maintain employment and capacity. The choice will likely be framed in terms of either reducing regulatory costs, increasing protectionist trade practices, condoning substantial price increases, or providing economic assistance through such measures as the acceleration in depreciation schedules now being considered by Congress in the form of the Jones-Conable Capital Cost Recovery Act of 1979 (H.R. 4646). This Act would reduce the period for depreciation of machinery to five years. This is a substantial improvement, from the industry's perspective, over the original 18 years for equipment (14.5 years with the Asset Depreciation Range system), and even over the recent Treasury Department's reduction to 15 years (12 years with ADR) which the industry deemed inadequate. The problem with the accelerated depreciation approach of H.R. 4646 is that all the capital spending projects a steel company may have are rendered more attractive with accelerated depreciation; that is, H.R. 4646 would not alter the relative positions of alternative capital projects for both steel and non-steel projects of the mostly diversified steel companies.

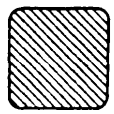
Since the diversification out of steel mentioned earlier continues to be a serious issue, this is a significant problem and points to the need for Congress to weigh the benefits of more technology specific federal assistance for the steel industry against the risks of either providing no assistance or in letting the steel industry choose how to use capital made available in some way by government action. There are technological options other than continuous casting which offer benefits to the industry; however, thus far, the OTA assessment has not revealed an option that can match the scope of the proven technical and economic benefits which continuous casting can readily provide to most of the domestic steel industry during the next decade.

FIGURE 1

TYPICAL CROSS-SECTION
AND
DIMENSIONAL CHARACTERISTICS"

SLAB

ALWAYS OBLONG
MOSTLY 2 TO 9 INCHES THICK
MOSTLY 24 TO 60 INCHES WIDE



BLOOM

SQUARE OR SLIGHTLY OBLONG
MOSTLY IN THE RANGE 6" X 6" TO 12" X 12"

BILLET

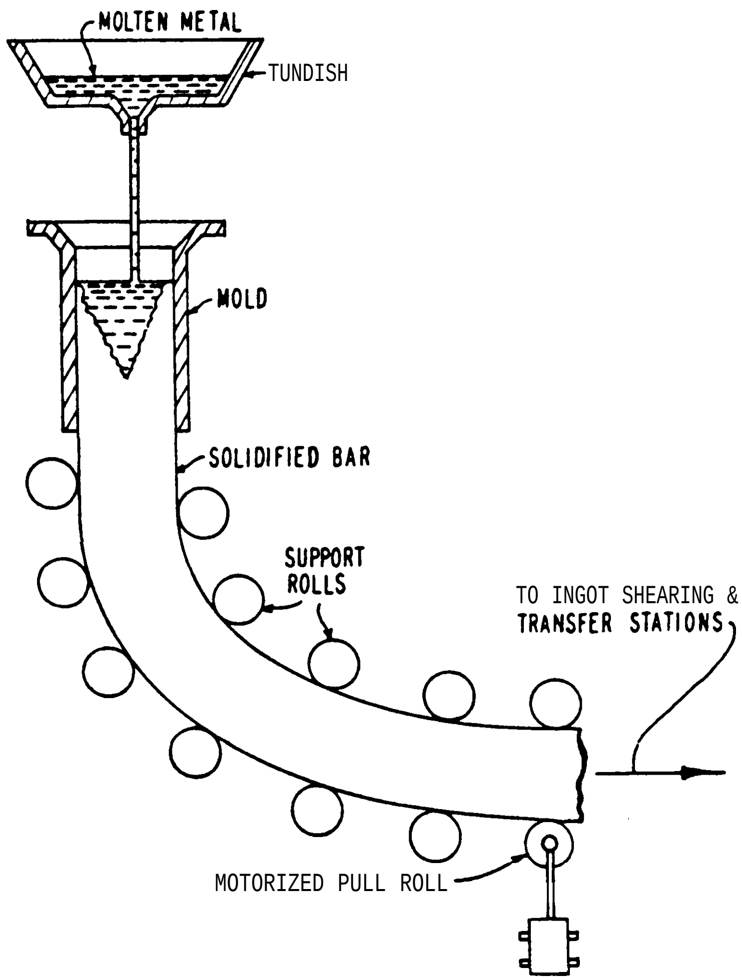
MOSTLY SQUARE
MOSTLY IN THE RANGE 2" X 2" TO 5" X 5"

•DIMENSIONS USUALLY GIVEN TO NEAREST ROUND NUMBER.
ALL CORNERS AR ROUNDED, AS SHOWN.

Comparison of the relative shapes and sizes of rolled steel governing nomenclature of products of primarynd billet mills. (Cast sections produced by continuous or bottom pressure casting methods are similarly designated when of the same general proportions and dimensions as their rolled counterparts.)

Source: The Making, Shaping and Treating of Steel, U.S. Steel Corporation, 1971,

FIGURE 2



CONTINUOUS CASTING APPARATUS

Source: Technology Assessment and Forecast, Ninth Report, U.S. Department of Commerce, March, 1979.

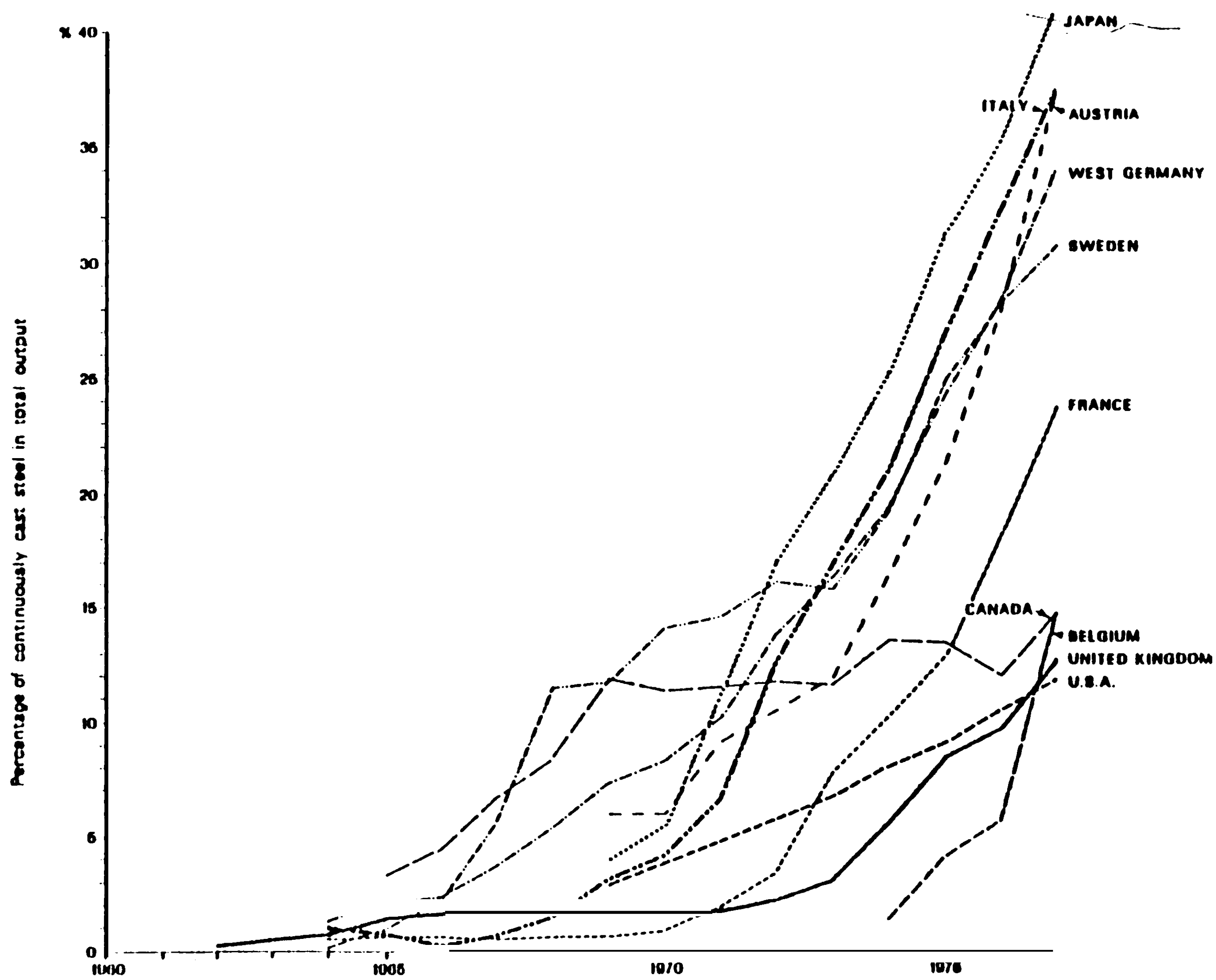


FIGURE 3 <u>The Diffusion of Continuous Casting</u>

Sources: O.E.C.D., I.I.S.I.

Table I

% Raw Steel Continuously Cast

Country	1969	1975	1977	1978
U.S.	2.9	9.1	11.8	14.2[1)]
Japan	4.0	31.1	40.8	50.9[2)]
Canada	11.8	13.4	14.7	20.2
Germany	7.3	24.3	34.0	38.0
France	0.6	12.8	23.6	27.1
Italy	3.1	26.9	37.0	41.3
U.K.	1.8	8.4	12.6	15.5

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1) Assuming that non-integrated plants account for 12% of the U.S. steel industry, their continuous casting usage is approximately 80% and accounts for 54% of the U.S. tonnage continuously cast, while integrated plants have a usage of 7.3%. AISI has reported that for the first half of 1979 the full industry usage rate was 16.1%.

2) A lower value of 46.2% has been reported by the International Iron and Steel Institute; presumably this figure is for calender 1978 while the 50.9% figure is for Japanese fiscal 1978 (April 1978-March 1979) and is indicative of the rapidly increasing usage.

Sources: AISI, IISI, Japan Steel Information Center.

TABLE II

SURVEY OF CONTINUOUS CASTING OUTPUT
(1973-1977)

	1973		1974		1975		1976		1977 (P)	
	000 t	%	000 t	%	000 t	%	000 t	%	000 t	%
Belgium	.	.	208	1.3	480	4.1	a	5.7	1,656	14.7
Denmark	.	.	.	.	73	13.1	312	43.2	347	50.7
F.R. of Germany	8,057	16.3	10.337	19.4	9,013	24.3	12.014	23.3	13,272	34.0
Fmn-	1,845"	7.3	2,756	10.2	2,771	12.9	4,212	in.o	5,209	236
Italy	3,375	18.1	5,165	21.7	5,904	27.0	7,559	32.2	&984	38.5
Luxemburg	.	.	.	.	.	.	.	.	.	.
Netherlands	.	.	.	.	.	.	.	.	.	.
United Kingdom (calendar)	832	"3.3	1,232	5.5	1,686	8.5	2,120	9.4	2,590	12.6
Total OECD	14,159	9.4	19,698	12.7	20,727	16.5	26,910	20,0	32,058	25.4
Austria	505	11.9	766	16.3	866	21.3	1,244	27.8	1,532	37.4
Finland	1,256	" 77.8	1,290	77.9	1,233	76.3	1,255	76.1	E 1,810	83.8
Norway	120	12.5	143	15.7	140	15.7	E 150	E16.9	E 120	17.0
Prrtugal	E 28	E5.5		7.5	35	7.9	69	15.0	E 200	37.6
Spain	2,038	18.9	2,218	19.3	2,333	21.0	2,493	22.7	2,666	25.8
Sweden	569	15.7	1,156	19.3	1,390	24.8	1,451	28.2	1,214	30.6
Switzerland	.	.	.	.	.	.	.	.	.	.
Turkey	.	.	.	.	.	.	.	.	.	.
Yugloslavia	.	.	.	.	330	11.3	398	14.5	523	25.9
Others	..	..	..	..		..	..	..	..	..
Total Western Europe	18,995	10.6	25,301	13.6	27,054	17.5	33,970	20.7	40,623	26.1
United States	9,270	6.8	10,722	8.1	9,653	9.1	12,246	10.5	E13,350	E11.8
Canada	1,551	11.6	1.873	13.8	1,735	13.3	1,582	12.0	1,992	14.7
Argentina			574	26.1	565	25.6	665	. 27.4	E 620	E23.1
Brazil	228	"3.2	379	5.1	477	5.7	1,119	12.1	1,957	17.4
Chile	7	1.3	9	1.4	7	1.4	11	2.2	11	2.0
Mexico	576	121	650	12.7	695	13.2	682 '	12.9	722	E13.0
Venezuela										
Total Latin America (Listed Countries\		..	1,612	9.7	1,744	10.0	2,477	13.5	3,310	15.9
USSR	6,%8	6.3	7,355	5.4	9,729	"6.9	11,729	8.1	12,200	8.3
Bulgaria	.	.	.	.	.	.	.	.	.	
Czecoslovakia	92	0.7	91	0.7	69	0.5	107	0.7	110	" 0.7
Eastern Germany	398	6.8	481	7.8	525	8.1	566	8.4	623	9.1
Hungary	59	1.8	422	12.2	775	21.1	1,019	27.9	1,054	28.3
Poland	309	2.2	320	2.2	332	22	297	1.9	446	2.5
Romania	.	.	.	.	.	.	.	.	.	.
Total Eastern Europe	858	1.8	1,314	2.7	1,701	3.3	1,959	3.7	2,233	3.9
Australia	133	17	223	2.9	47	0.6	-	.	.	.
India				..					..	..
Japan	24,716	207	29,411	25.1	31,808	31.1	E37,733	35.1	41,807	408
Republic of Korea	..			..	..		770	21.9		32.0
South Africa	917	16.0	1,105	18.9	1,425	20.9	1,861	26.2	2,714	37.1
Total of listed Countries	64,219	9.7	78,916	11.7	84.897	13.9	" 104,357	16.2	119,569	18.7
Percentage of World Steel Output Covered	95.3%		95 .27		94.5%		95.5%		94.8%	

Source: Iron and Steelmaker 1978,

Table III Economic Costs and Benefits of Adopting Continuous Casting[1] (CC)

% CC	Incr. in CC Tonnage (Thousands of Tons)	Energy Saved 10^{12} BTU	Incr. in Yield	Incr. In Steel Shipped (Thousands Tons)	Total Steel Shipments (Thousands Tons)	New Industry Yield	CC Capital cost[2] $/ton	Total CC Capital cost $mill.	Deer. cost/ Incr. Profit[3] $/Ton	Total[4] Annual Benefit $mill.	Return on Invest- ment	Payback Period yrs.
25	14,800	44.1	0.10	1,480	99,415	.73	40	592	25	185	0.31	3.2
							40	592	50	222	0.38	2.7
							60	888	25	185	0.21	4.8
							60	888	50	222	0.25	4.0
			0.12	1,776	99,711	.73	40	592	25	192	0.33	3.1
							40	592	50	237	0.40	2.5
							60	888	25	192	0.22	4.6
							60	888	50	237	0.27	3.8
							60	888	75	281	0.32	3.2
							80	1,184	75	281	0.24	4.2
50	49,058	147.2	0.10	4,906	102,841	0.75	40	1,962	25	613	0.31	3.2
							40	1,962	50	736	0.38	2.7
							60	2,944	25	613	0.21	4.8
							60	2,944	50	736	0.25	4.0
			0.12	5,887	103,822	0.76	40	1,962	25	638	0.33	3.1
							40	1,962	50	785	0.40	2.5
							60	2,944	25	638	0.22	4.6
							60	2,944	50	785	0.27	3.7
							60	2,944	75	932	0.32	3.2
							80	3,925	75	932	0.24	4.2

1) Base Case; 1978 CC usage = 14.2% or 19,458,000 net tons of 137,031,000 nets tons of raw steel production assumed to remain constant; total domestic shipments = 97,935,000 net tons; yield = .715; all calculations done for replacement of ingot casting in integrated (blast furnace-based) plants by CC.

2) Three levels of capital cost for CC have been used: $4O/ton is somewhat greater than recent expenditures by National Steel for a major facility; $60/ton has often been quoted and may be appropriate in those situations where ingot casting facilities to be replaced have not been fully depreciated or where more complex shapes are being cast; $80/ton is undoubtedly a high cost estimate but may be realistic for those cases where downstream finishing facilities must be added to take advantage of increased capacity resulting from a greater yield.

3) Decreasecost/incrcascd profit (for the increse steel shipped) resulting from the hot metal-purchased scrap differential and the normal operating pofit.

4) Total annual benefit is calculated on the basis of a $10/ton combined savings for the additional CC tonnage and the product of the increase in steel tonnage shipped and the hot metal to scrap savings; the latter is undoubtedly a crude but conservative estimate of the additional profit resulting from increased yield and capacity; there is substantial. company to company variation in both hot metal production cost and net income per ton shipped.

TABLE IV

UNITED STATES STEEL INDUSTRY PROFITS
AS A PERCENT OF STOCKHOLDERS' EQUIly: 1950-78
(after taxes)

	Return onl Equity	
Year	Primary Iron Steel	All Manufacturing
1950	14.3	15.4
1951	12.3	12.1
1952	8.5	10.3
1953	10.7	10.5
1954	8.1	9*9
1955	13.5	12.6
1956	12.7	12.2
1957	11.4	11.0
1958	7.2	8.6
1959	8.0	10.4
1960	7.2	9.2
1961	6.2	8.8
1962	5.5	9.8
1963	7.0	10.3
1964	8.8	11.6
1965	9.8	13.0
1966	10.3	13.5
1967	797	11.7
1968	7.6	12.1
1969	7.6	11.5
1970	4.3	9*3
1971	4.5	9.7
1972	6.0	10.6
1973	9.5	12.8
1974	16.9	14.9
1975	10.9	11.6
1976	9.0	14.0
1977	0.1	14.2
1978	7.3	15.3

Note: The annual data represent the average Of the quarters in the year.

Source: Federal Trade Commission, Bureau of Economics, Quarterly Financial Report, various years.