THE ENERGY SITUATION IN THE FERRO-ALLOYS INDUSTRY AND ITS IMPLICATIONS FOR THE FUTURE

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(presented by Mr. Arnesen)

SYNOPSIS

This paper briefly describes today's world energy situation, and emphasizes the extensive dependence of industrialized countries on imported oil. Some of the factors which retard the substitution of oil with other forms of energy are discussed.

The energy component in the production of important alloys is reviewed, and the implications of the probable future energy situation for the ferro-alloys industry are discussed.

In the long run, reallocation of ferro-alloys production is considered probable.

On a short term basis, the industry will respond with measures to utilize energy more efficiently.

The Energy Situation in General

The industrialized world received its first energy shock in 1973, when the crude oil price suddenly quadrupled, and oil no longer flowed freely. For the first time, nations became seriously interested in the global energy situation and realized how vulnerable most industrialized countries had become as a result of their dependence on imported oil.

But this initial shock should not have come as a surprise. Although the situation evolved from the Middle East conflict, everyone who was concerned about the long-term prospects for production and consumption of oil had warned about a coming oil crisis years before.

In 1979, the industrialized world experienced its second energy shock, this time, with a doubling of oil prices during the year. This development in crude oil prices is shown in absolute and in 1977 dollars in Figure 1.

After the 1973 crisis, the world should have foreseen another such crisis and taken measures to soften the blow. However, only a very limited effort was made.

Figure 2 shows the development of oil consumption in some parts of the world from 1960 to 1978. The effect of the 1973 crisis is clearly visible, but previous trends towards increased consumption gradually resumed. Notable exceptions are Japan and Western Europe.

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Figure 3 shows world wide energy consumption for the years 1968, 1973 and 1978 in terms of distribution over the primary energy sources, and clearly illustrates the world's dependence on oil, which in 1978 constituted 46% of total world energy consumption. The contribution from oil is only slightly lower than in 1973 when it represented 48% of total consumption. In absolute figures, world oil consumption increased 11% from 1973 to 1978.

Figure 4 illustrates world oil production and consumption in 1978, showing the industrialized Western World's dependence on oil imports.

Under normal circumstances, a large increase in price for one primary energy source should lead to substitution by alternative energy sources, to the extent such sources are available. We can conclude that there has been only a limited amount of substitution, and it may be of interest to explore why.

Table 1 shows 1978 figures for consumption and reserves of the more important primary energy sources in the world, presented as tons of oil equivalent. The third column illustrates the lifetime in years with continued 1978 production levels.

TABLE 1 - CONSUMPTION, RESERVES AND LIFETIME OF RESERVES FOR PRIMARY ENERGY SOURCES

All figures are for 1978			
Primary energy source	Consumption/ year	Reserves	Lifetime for constant 1978 consumption
	Mill. t.o.e.	Bill. t.o.e.	Years
Oil	3076	88.1	29
Gas	1241	60.5	49
Coal	1811	426.8	236
Nuclear	152		20
Hydro	404	1.58 per year	∞

Alternative energy sources to oil are obviously available, mainly coal. The potential for hydroelectric energy is limited, though very important in certain areas. In the nuclear field, higher fuel prices or new technology will have to be implemented, in order to increase the lifetime of the fuel resources. Breeder reactor technology will increase these by a factor of 70, so that nuclear energy is still a very interesting potential contributor of energy for the future. The power price from a breeder reactor is, however, considerably above normal nuclear reactors.

Substitution between alternative energy sources is slow for a number of reasons.

Development of new coal mines is a lengthy and costly process, which to an increasing degree is hampered by environmental regulations. In addition, in some countries the coal industry is not profitable and has to be subsidized. Generally, it takes time to reverse trends in an industry which has been in decline for years in many countries. It is thus probable that it will take a long time for the coal industry to satisfy an increased demand, and coal will become more expensive. Coal prices will presumably be based mainly on costs, and a situation similar to oil pricing is unlikely.

In the years 1973 - 1978, the average annual growth in world coal consumption was 2.2%, compared to 2.0% for oil.

The fate of nuclear energy generation is well known. Questions have been raised about the possible hazards of operation and the safety of indefinite storage of spent nuclear fuel. Nuclear power has suffered severe setbacks in USA, Canada, Sweden and Austria. In addition, it takes an increasingly longer time to establish new capacity and previous cost estimates for nuclear power plants have proven too low. Nuclear power will be more expensive, and can offer no speedy improvement in the general energy situation.

Hydroelectric power plays an important role in some parts of the world, but its contribution to world energy consumption is small, and the potential in this sector limited. So, this can offer no great relief on a global basis. For ferro-alloys production, however, hydroelectric power will continue to be of great importance in some areas.

The "new" energy sources, like solar energy, wind, wave or geothermal power are decades away from playing any significant role in the world's supply of energy.

We are thus left with a situation where the world for decades will be strongly dependent on an oil situation which has been labile for years, and where pricing has long since had any bearing on production costs, but is determined by what customers are willing to pay to maximize revenues of the oil producing nations. Energy costs will, therefore, probably increase more rapidly than other costs.

Energy Consumption in Ferro-Alloys Production

At this stage, it is of interest to examine energy consumption in the ferroalloys industry, in order to determine the effect of the energy situation on the industry.

On the basis of a few simple assumptions and figures for ferro-alloys tonnage from recent years, electric energy consumption is as shown in Table 2.

TABLE 2 - THE WORLD'S APPROXIMATE POWER CONSUMPTION FOR PRODUCTION OF TONNAGE FERRO-ALLOYS

Alloys	Energy Consumption Twh/year
Si alloys	31
Mn "	14
Cr "	10
Total	55

If we assume a 3% increase in steel production and alloy consumption, an additional 1.65 Twh/year is needed for ferro-alloy production. Comparing calory for calory, this is equivalent to 0.14 mill. t.o.e./year, or roughly 0.1% of the yearly increase in primary energy consumption world wide.

So therefore, even if a calory for calory comparison between oil and electricity is only partly valid, the increase in energy necessary for ferro-alloys production is not going to be a decisive factor in the world's future demand for energy. Energy will be available for such production in the coming decades. The interesting question is what the price will be.

Table 3 shows the cost of electric power generated by different forms of primary energy:

TABLE 3 - COST OF ELECTRIC POWER FROM NEW LARGE POWER STATIONS

	Hydro-power	Thermal power		Nuclear power
		Coal-based	Oil-based	
Fixed costs	1.0-2.0	0.8	1.1	2.0
Fuel costs		1.5	3.2	0.9
SO_2 - removal from combust-ion gases		0.7	0.7	
Total	1.0-2.0	3.0	5.0	2.9

All figures in U.S. cents per KWh.

This table was published in the fall of 1979 (1) and later developments have further increased oils handicap.

How sensitive then, are the ferro-alloy producers to electric power prices?

Table 4 shows the approximate proportion of production costs for some ferro-alloys constituted by electric energy.

TABLE 4 - ELECTRIC POWER PRICE IN % OF TOTAL PRODUCTION COSTS

(Capital costs excluded)	
FeSi 75	30 - 40
FeMn	10 - 20
HCFeCr	10 - 20
FeW	2

As could be expected, the electric power price is far more important in ferro-silicon production than in ferro-manganese or ferro-chromium production, and in a special alloy like ferro-tungsten, the electric power price is of minor significance.

<u>What Impact Will the Energy Situation Have on the Ferro-Alloys Industry in the Future?</u>

The future consumption of ferro-alloys depends mainly on two factors:

- the total steel production
- the consumption of ferro-alloys per ton of steel.

Figure 5 illustrates the UNIDO forecast for steel production, based on the so-called pessimistic growth curve. This shows an approximate doubling of steel production between 1980 and 2000.

It is very difficult to predict future developments in the consumption of ferro-alloys per ton of steel. At present, two trends are counteracting each other:

The use of more efficient alloying techniques will tend to decrease the amount of ferro-alloys per ton of steel.

An increasing proportion of alloyed steels will lead to an increase in the consumption of alloys per ton of steel.

For our discussion, we may assume that the two trends will more or less balance out, and that world ferro-alloys production will need to double in the next 20 years.

Even if energy consumption per ton of alloy remains unchanged in the future, we believe that the energy can be made available for such an expansion in our industry without creating great problems. This energy will, however, become more expensive. Based on this fact, we assume that the impact of the energy situation on the ferro-alloys industry in the future will be twofold:

- A trend toward establishing new industry in areas where reasonably priced power is available
- An increasing pressure to reduce energy consumption in the processes

We shall now look more closely at these two factors:

Factors Influencing Future Location of Ferro-Alloys Industry

As shown in Table 3, hydroelectric power can be produced less expensively than alternative power, and is thus preferred. Table 5 illustrates the potential of hydroelectric power, especially in South America, Africa, Asia and Oceania. The possibilities in Europe and North America are very limited, with the exception, perhaps, of Iceland and Canada.

TABLE 5 - TOTAL WORLD POTENTIAL OF HYDRO-ELECTRICITY

	Total regional potential in % of world total	Existing capacity in % of total regional potential
Europe	7	55
North America	14	30
South America	14	7
Africa	22	1
USSR	11	11
Asia	30	6
Oceania	2	14
World	100	

(Source: World Power Conference, 1974)

The market value of electric power depends largely on local conditions. If the hydroelectric potential is near large markets, the power plants will most probably feed into systems mixed with thermal power, and prices will be high. On the other hand, in isolated areas there may not be many customers for potential hydroelectric power. In such cases, energy intensive production, such as ferro-alloys, aluminium, etc., may be a good way to utilize this potential power. We anticipate this development in some of the areas mentioned above. However, there are numerous factors which may slow down this development. Some of the projects will be very large, involving huge investments in hydroelectric power generation plants, and metal production plants. Such huge projects will require a minimum of 10 years lead time.

Another factor which may tend to slow down this development is political instability in some of the countries concerned, as well as the difficulty of attracting sufficient capital under such circumstances. A third factor inhibiting this development may be the fact that some greenfield projects in remote areas tend to become very expensive, mainly because of the lack of costly infrastructure, the high cost of obtaining qualified personnel and excessive transportation and building material costs.

Natural gas is another potential primary energy source where local prices may be low. Long distance transport of natural gas is fairly expensive. There are large amounts of natural gas in the Middle East with no large markets in the immediate vicinity. Other potential locations are in Africa, and in the USSR and China. Large industrial developments based on this available gas are already completed or under way in the Middle East. Recent trends in gas pricing, however, may lead to an increasing transport of natural gas over longer distances, and to reduced amount of cheap natural gas available at the wellhead.

Reasonable power may also be available where there is an abundance of easily mined coal which can be used for electricity generation. Favourable locations here are the United States, the Soviet Union, China, South Africa and Australia.

In areas where nuclear power is available electric power may be offered at comparatively attractive prices for ferro-alloys production.

But availability of electric power is not the only factor that will influence the location of future ferro-alloys industry. Another very important factor is the availability of raw materials. The uneven distribution of chromium and manganese ores in the world is well known, and the countries possessing these minerals will probably play an even more important role as producers of these ferro-alloys.

Finally, the location of ferro-alloys industry will also be influenced by political factors. Japan, for instance, will probably maintain a ferro-alloys production of a certain size, even if they could import material at more favourable prices. If nothing else, the development in oil prices has taught the industrialized nations that it is dangerous to become too dependent upon the import of strategic materials.

On the other hand, political decisions may also influence ferro-alloys production in other ways. Environmental considerations will certainly influence further development of coal, oil, gas and nuclear potentials and may even prevent the development of hydroelectric potential.

So the factors influencing the location are complex, and do not provide a very clear picture. However, the large steel producing nations will continue to produce a fair amount of the world's ferro-alloys, but there will be a gradual shift in production towards the raw material producing countries, and towards locations where power is available at favourable prices.

How can the Ferro-Alloys Industry Economize on Energy?

Rising energy prices will lead to increased efforts to save on energy in the processes. Such efforts will be made in all three fields open to operators:

Optimization of Processes - including processes for preheating, prereduction, etc., and the best possible process equipment, providing high operating efficiency.

When optimizing the processes however, it is important not to sub-optimize on electric energy alone, but to include all forms of energy in the evaluations.

Optimization of Raw Materials - including agglomeration, sintering, screening, more reactive raw materials, etc.

Optimization of Operation - including improved instrumentation, the use of process computers, etc.

A number of the papers presented at this conference relate to these areas. This paper will only touch upon two points where I feel developments will be rapid in the near future:

- Energy recovery from semi-closed ferro-silicon furnaces
- Closing of ferro-silicon furnaces and utilization of energy from such furnaces.

Energy Recovery from Semi-closed Ferro-silicon Furnaces

Figure 6 shows the heat balance of a 45 MVA ferro-silicon furnace. The energy content of the furnace gas corresponds to about 82% of the electrical energy input, and this represents an interesting potential for recovery. Such recovery possibilities are described in Grong's article from Bjølvefossen (2). As correctly pointed out in this article, the amount of energy in the furnace gas may vary considerably, mainly due to the composition of the reducing agents and the efficiency of furnace operation. But typically, the amount of energy in the furnace gases are equivalent to the electrical input to the process.

A major proportion of this energy may be recovered in a steam boiler, and the steam may be used for regeneration of electric energy. Grong reports in 1978 that 20-25% of the electric energy to the furnace may be regenerated in this way. Mr. Bromet, who is also a speaker at this conference, reports that 20% is expected to be regenerated from CUAEM's 50 MW ferro-silicon furnace in Dunkerque. Mr. Tomioka, also at this conference, reports regeneration from a 32 MVA ferro-silicon furnace in JMC's Nakagawa plant of 5 MW. It is clear that these installations have pioneered regeneration of electric power from ferro-silicon furnaces, and that some problems may have been encountered. But the technique is now available, and the interesting question now is what will be the price for such regenerated energy.

Grong's figures from a few years back indicate a regenerated power price of about 1.5 US cents/kWh. Bromet's figures show about 2.0 cents/kWh. On a project in our own silicon metal plant, Fiskaa Verk, we have also concluded that based on today's prices, the cost for regenerated energy will be about 2.0 cents/kWh. Adjusting Grong's figures for exchange rate and inflation, there seems to be a fair correspondence between the figures quoted.

A power price of 2.0 cents/kWh looks attractive to many smelters even today, and in the future this will be the case to an increasing degree. A large number of energy recovery projects will undoubtedly be realized in the years ahead.

Another interesting possibility for recovered energy is to utilize it directly in the form of heat, without transforming it with low efficiency, to electricity. Such installations have been operated by Vargön in Sweden (steam) for years and for two years by Ila og Lilleby in Norway (hot water).

A project is now being investigated by our Fiskaa Verk in Norway, where a combination of regeneration of electricity and utilization of heat in the form of steam seems to be the best solution.

Energy Recovery from Closed Ferro-silicon Furnaces

As Mr. Bromet has shown in his paper, a closed ferro-silicon furnace has some very attractive features - good environment at the top of the furnace, and very low gas volumes to handle. After more than 3½ years of operation of a 8.5 MW closed 75% ferro-silicon furnace at our Bremanger plant, we now feel that our split furnace body concept technically solves operation of such a closed furnace, since this system eliminates all necessity for poking in the charge.

The disadvantages of wet scrubbing gas from a closed ferro-silicon furnace include the need to purify the water and the problems with handling and disposing of large quantities of sludge. These problems can be solved. But, in our company, we have found a better solution. We are developing a dry gas cleaning system capable to withstanding the temperatures experienced in gases from closed furnaces. We have been testing such a system on different processes on a small scale for years. We have aimed at maximizing safety and minimizing the need for cooling the gas in our system. The first full-scale installation is connected to our closed 8.5 MW ferro-silicon furnace, and has been undergoing tests since June this year.

A successful solution to dry gas cleaning at elevated temperatures would eliminate some of the problems encountered in wet scrubbing.

Based on our experience so far, we have reason to believe that all SiO reacts immediately on the furnace top, probably through reoxidation with small amounts of CO_2 or H_2O in the furnace gas, and probably also through the reaction:

$$SiO + CO = SiO_2 + C$$

In our experience, the same amount of energy will be available in the gas from a closed ferro-silicon furnace with dry gas cleaning as from a semi-closed furnace. It is possible to burn this clean gas under close to stoichiometric conditions in a boiler, and obtain considerably higher combustion temperature than in the gas from a semi-closed furnace. On the basis of certain assumptions, we have found that 21% more energy can be recovered in this way from a closed ferro-silicon furnace as compared to the semi-closed, even if we assume a 10% lower fixed carbon consumption in the closed furnace and allow for the energy needed for gas cleaning, including extra filtration of taphole smoke from the closed furnace. A calculation like this is admittedly very sensitive to a number of variables, but emphasises that a successful development of dry gas cleaning improves the energy recovery from the closed ferro-silicon furnace as compared to the semi-closed alternative. Another interesting alternative that we are now exploring is to burn unclean gas in the steam boiler system, and to clean the exhaust gases in normal dry filtering units. Also, this system eliminates the need to cool down the gas, but exhaust gas volume from the boiler increases. As I have stated before, I believe that the energy recovery possibilities will be increasingly important in the future.

Conclusions

The industrialized Western World is heavily dependent on imported oil.

The move away from imported oil to alternative energy sources is slow, and our dependence on oil will continue for decades. Coal prices are likely to increase, since coal is the only energy source capable of replacing a significant part of the oil in the next two decades.

The proportion of the world's energy consumed in the production of ferro-alloys is not significant, and it is probable that energy will be available without serious problems, even for increased ferro-alloys production in the future. The development of energy prices will, however, have an impact on the location of future production. Sites where electric power is available at attractive prices, whether this be generated from hydro, gas, coal, or nuclear fuel,will be preferred, but raw material availability and political factors will also influence future locations. In some areas political instability and high costs may make location unattractive, even with favourable power prices.

There will be an increased pressure on the producers of ferro-alloys to switch to energy efficient processes and raw materials, and to optimize their operations. There will be an increased trend to recover energy from the production processes, whether this be in the form of lower temperature calories from semi-closed furnaces, or in the form of CO-rich gas from closed furnaces.

References:

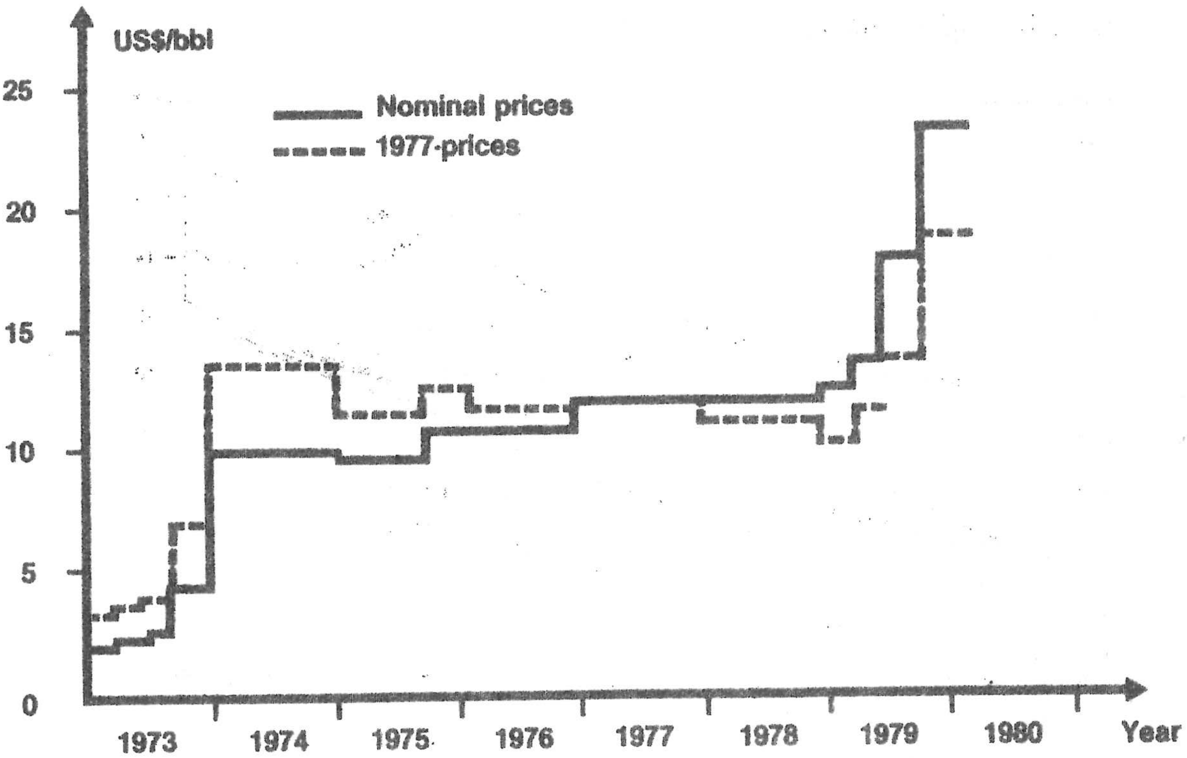
1. NORDHEIM, Rolf: Energy and Demand Influences on Future Development of Ferro-silicon. Presented at Metal Bulletin's Second International Ferro-Alloys Conference, Copenhagen, Oct. 1979.

2. GRONG, Tor: Energy Recovery from electric Ferro-silicon Furnace Waste Gas. Working Document presented at the Ferro-Alloys Congress, Acapulco, Mexico, May 14 - 18, 1978.

3. KROGSRUD, Harald: Double Rotation Paves way to Ferro-silicon Furnaces. Presented at the ILAFA International Congress on Ferro-Alloys, Acapulco, Mexico, May 14 - 19, 1978.

Figure 1

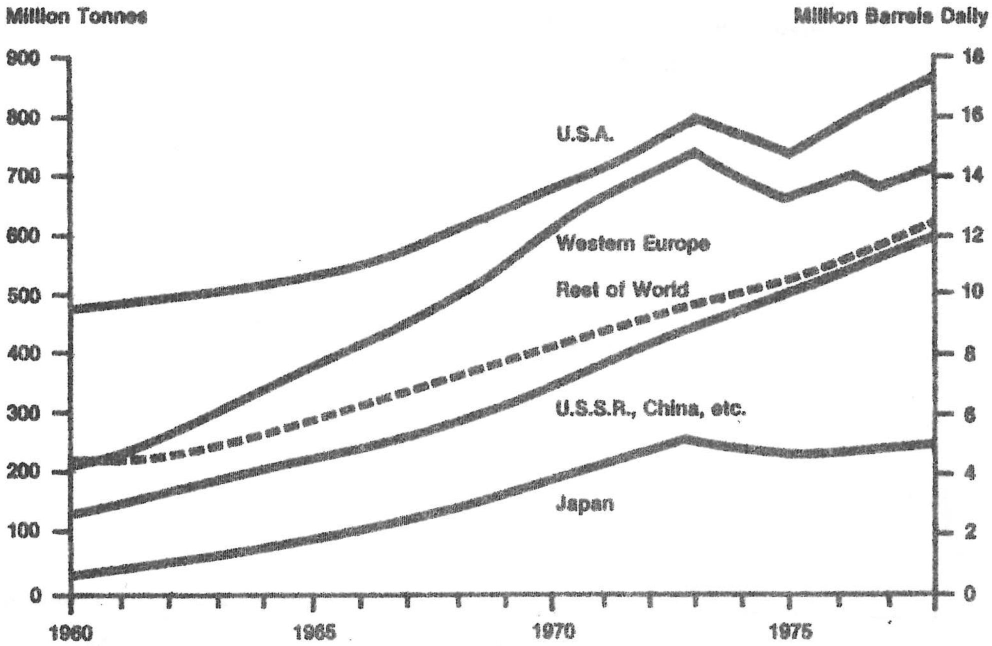
Development in prices of Arabian light crude, FOB Persian Gulf (Ras Tanura)



Source: St. meld. nr. 54 (1979-80), Norway, 1980.

FIGURE 2

World Oil Consumption 1960 - 1978

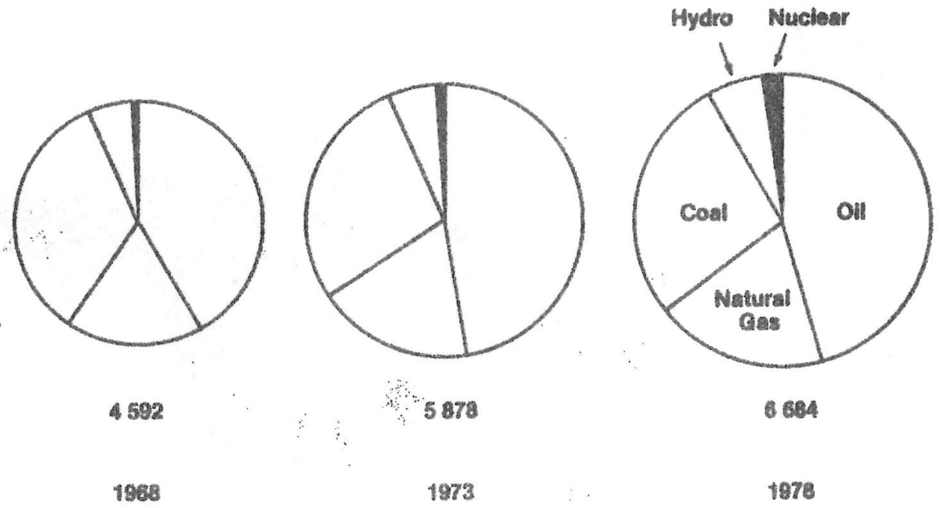


Source: BP statistical review of the world oil industry, 1978.

FIGURE 3

World Primary Energy Consumption 1968, 1973 and 1978

Million Tonnes Oil Equivalent

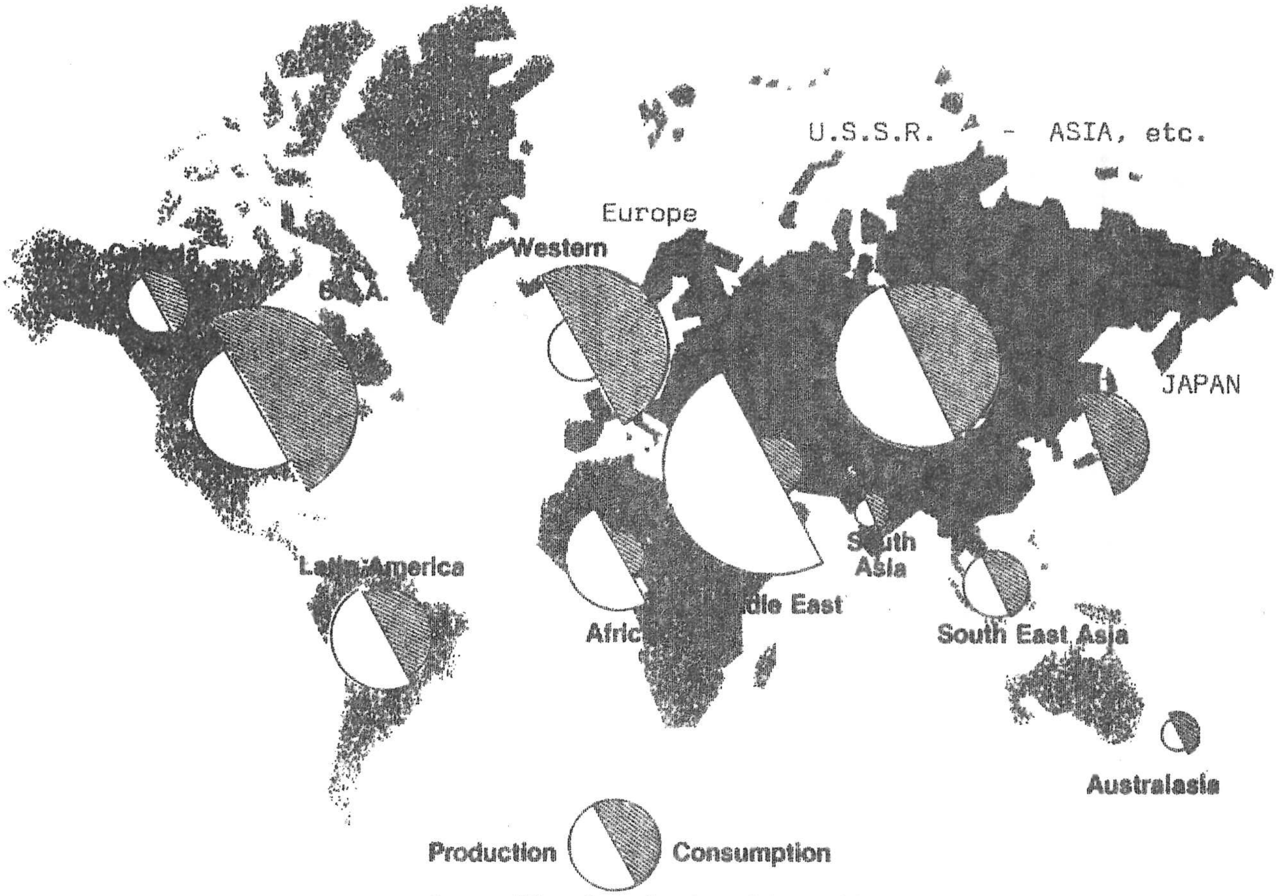


Source: BP statistical review of the world oil industry, 1978.

FIGURE 4

World Oil Production and Consumption 1978

Million Tonnes



Source: BP statistical review of the world oil industry, 1978.

Figure 5

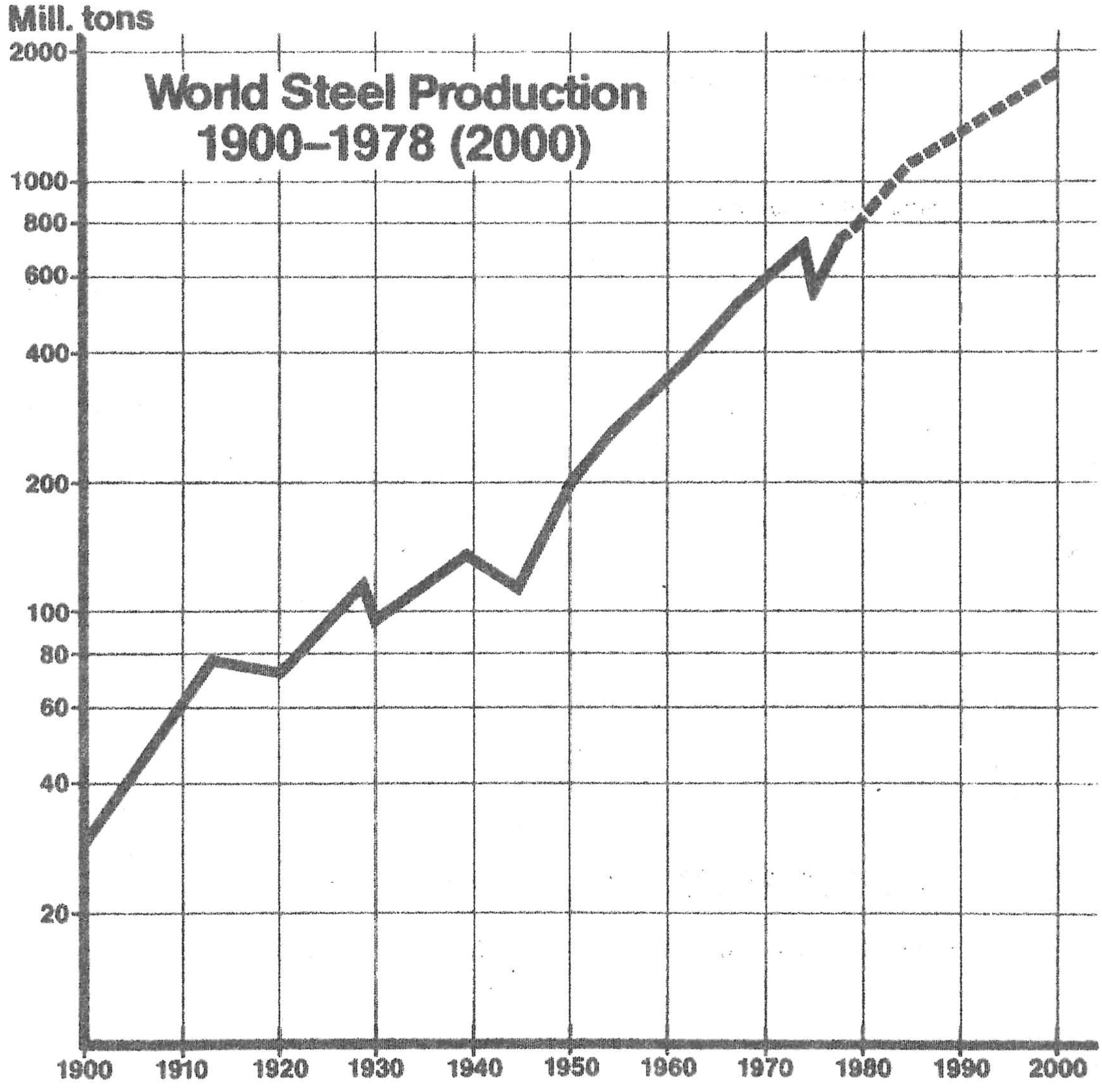
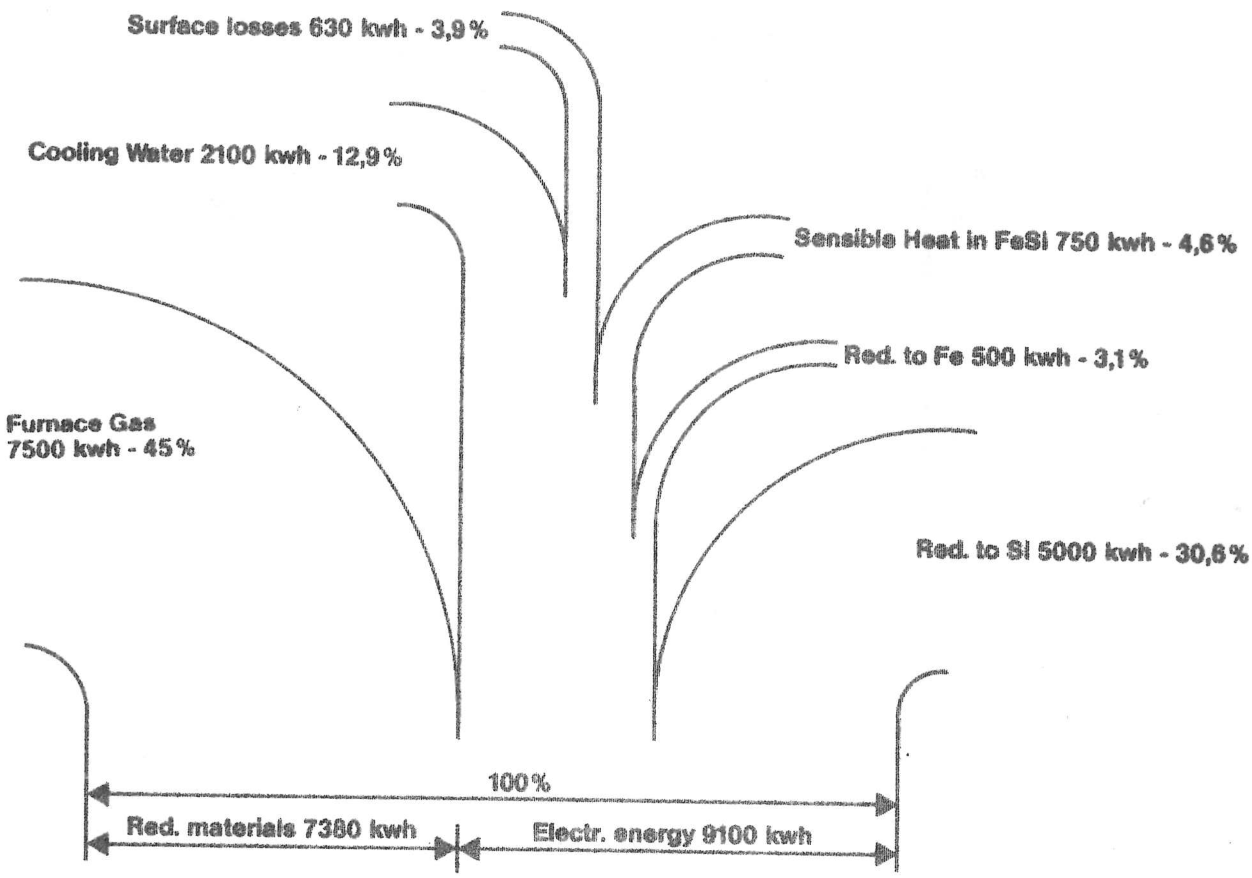

Mill. tons
World Steel Production
1900–1978 (2000)
2000
1000
800
600
400
200
100
80
60
40
20
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

Figure 6



Simplified Heatbalance for 45 MVA FeSi furnace (kwh-values per ton metal)

DISCUSSION

Mr. E. Hällgren*

I am very grateful to Mr. Arnesen for the words he has said to us regarding the energy situation because it will absolutely become worse in the times to come and we need to take steps against that.

I have noticed a few words in the written text which, I think, need a comment. It says 'some problems may have been encountered' when you talk about the recent installations of heat recovery in combination with steam turbines. I believe that many of us know that these problems have had such an extent that the wording 'some problems' is a great understatement, and anyone of us who wants, or plans, to install heat recovery in his plant needs guarantees for two things : The first is that the heat recovery installation must not have an adverse influence on the metal production. The furnace must always be the most important item and absolute priority must be given to the production of metal. The second is that the heat recovery really works so that it can pay for the money invested in it. I am afraid that the two installations you mentioned have not lived up to either of those two requirements. They may therefore scare other people from installing heat recovery, if they are afraid to be hurt by the same bad behaviour of the equipment. This can cause damage to the whole industry we are representing here, because we need, as Mr. Arnesen stated, recovery of energy. The bad behaviour of the installations cannot be compensated by the most beautiful coloured commercial leaflets showing how the installation is meant to work.

But, as I stated in the discussion on Monday, these problems are already solved and that was 20 years ago, and I would recommend anybody who plans to install heat recovery to study the Journal du Four Electrique, the issue of May 1977. There is an extensive article regarding the installations we have in Vargön and you know they have been very successful. There are three of them in the same plant which is in itself a good guarantee. The article is in French, but I can supply the text in English to anybody who wants it. So, my advice if you want to install heat recovery is to look closely at your supplier : Has he succeeded earlier or has he not ? Is he a new beginner or is he an experienced manufacturer ?

Mr. A.G. Arnesen :

Mr. Hällgren's comment is a very timely one. Frankly, I think that your observations are very correct. The energy recovery systems must not have an adverse effect on the furnace because then your energy becomes very expensive. This is extremely important. But also, when you now have a furnace, a hood, a boiler system and a steam turbine system, in series in the system, it is more vulnerable than it was before. Thus, it is very important to take these separate points and eliminate the problems and make this work on a steady basis.

Mr. A. Das Gupta**

I note from Mr. Arnesen's paper that he has confined all this discussion to silicon alloys which presumably consume the maximum power but, I wonder if he can throw some light on the ferro-chrome and ferro-manganese production. What methods would he suggest for the energy conservation in this case ?

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Mr. A.G. Arnesen :

I think that Mr. Das Gupta's comment is a very fair one. I concentrated on the silicon alloys mainly because they have been the slowest in recovering gas and energy although, as we already heard, Vargön did this 20 years ago. Most of us have not started this. For ferro-manganese or chromium alloys it is easier to close the furnace and recover the energy in the form of gas. This gas can be used for various uses. If you have a chemical industry that can use the gas you can pipe it to them or you cán use it as a fuel. So actually, heat recovery or energy recovery from closed furnaces has been normal for a number of years, but I agree it is just as important as for the other silicon alloy furnaces.

Mr. E. Hällgren

I can answer the question about heat recovery from ferro-chrome production by saying that we have used the same furnaces for production both of silicon 75 and of high carbon ferro-chrome. The steam production when you go from 75 % ferro-silicon to chrome decreases depending on several factors. You could calculate, I think, with about 2/3 of the steam production at chrome compared to ferro-silicon. When I say ferro-silicon, I mean ferro-silicon with a reducing agent solely consisting of coke.

Dr. D. Slatter*

I should like to follow along the question of the previous delegate. Although not directly concerning the ferro-alloy industry it is nevertheless relevant in energy conservation terms and is relevant also to some work we have been doing in Zimbabwe. Can Mr. Arnesen give us some ideas as to whether they have done any installation or investigations into energy recovery from calcium carbide production ?

Mr. A.G. Arnesen :

Again basically calcium carbide can be produced in semi-open furnaces, open furnaces or closed furnaces. Now in the case of a closed furnace, you can capture the gas, clean it and use it as fuel or for other purposes so there energy recovery is fairly easy. We have done some calculations on energy recovery from semi-open calcium carbide furnaces and our preliminary conclusions are that the amounts of energy available here are not large enough to make an installation worthwhile, but this again depends very much on the local power price.

Dr. P. Kallfelz**

I would like to make a few comments on your paper. You told us that you better should not suboptimize on the electrical energy only and I would say that you better begin to optimize on the electric energy because it implies so many other optimizations that you get your process into much better conditions in saving probably the same cost that you save in energy. In other words any measure you are taking to save energy will result in further savings, like in raw material yields and productivity. Would you agree to this ?

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* University of Zimbabwe, Zimbabwe; ** Monteforno, Switzerland

Mr. A.G. Arnesen :

I think this is again a very valid comment. When I talked about optimization, we all realized life is not only energy and energy prices. Other things enter into this, but I also think you are very right if you optimize on energy, you optimize on yields, etc., and you really gain the best of both worlds.