OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

United Nations Industrial Development Organization

Distribution
LIMITED

ID/WG.14/27
2 July 1968

ENGLISH
ORIGINAL: FRENCH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September – 9 October 1968

D01331

B-14-2

ENERGETICS OF IRON AND STEEL WORKS EVOLUTION AND APPLICATION TO DEVELOPING COUNTRIES[1]

by

J. Astier and P. Dancoisne,
France

---

[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.

United Nations Industrial Development Organization

Distr.
LIMITED

ID/WG.14/27 Summary*
2 July 1968

ORIGINAL: ENGLISH

Second Interregional Symposium
on the Iron and Steel Industry

Moscow, USSR, 19 September - 9 October 1968

B-14-2

THE ENERGETICS OF IRON AND STEEL PLANTS[1]

Evolution and application to developing countries

by

Jacques Astier and Paul Dancoisne,

France

SUMMARY

Introduction: Evolution of the energetics of iron and steel plants over the last few years, with average total energy consumption figures per ton of steel and breakdown of this consumption by source of energy.

Estimates of the energetics of modern plants using the most recent techniques, for:
- (a) Blast furnace
- (b) Electric pig iron furnace
- (c) Prereduction, using oxygen-blast or electric furnaces.

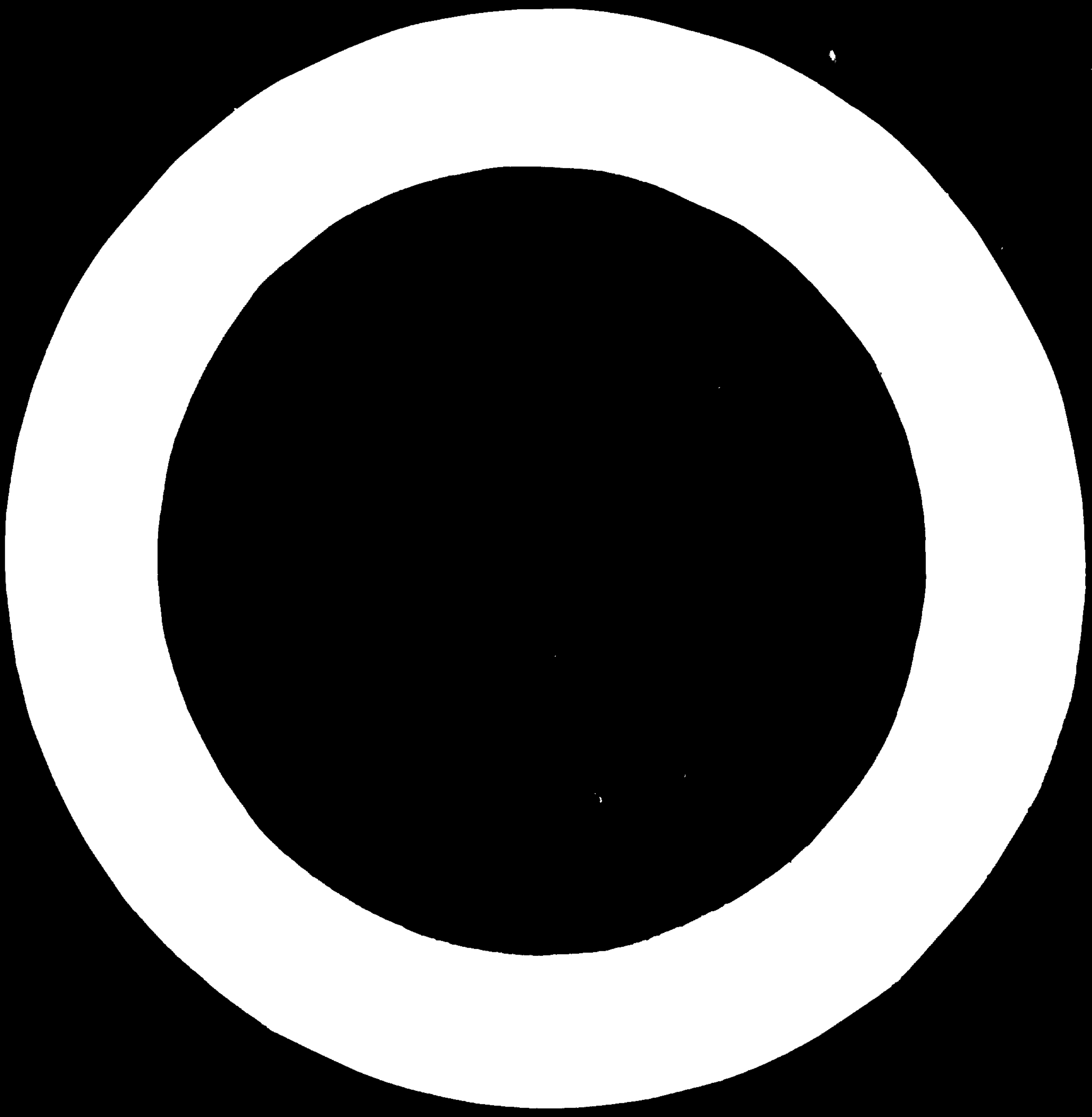
Application of the foregoing data to the concept of an iron and steel plant based on the use of coal (coking or non-coking), with a short examination of the possible use of charcoal.

Application of the same data to the concept of an iron and steel plant based on the use of liquid or gaseous hydrocarbons.

---

* This is a summary of the paper issued under the same title as ID/WG.14/27

[1] The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the author, without re-editing.



Application of the data to the concept of an iron and steel plant based on the use of electric power.

Some remarks on the possible advantages of dividing an iron and steel plant into an ore production works and a smelting and rolling works.

Possible advantages of such a line of action for developing countries as a result of transfers of investments and industrial activities from highly developed countries to developing areas where there are iron ore deposits.

Contents

List of figures

Introduction giving the evolution of energy balances of iron and steel works during the last years, and the mean values of total energy consumption per ton of steel, as well as its distribution among the various sources of energy.

Previsional energy balance of modern works using the newest technology and basing on blast furnace, electric ironmaking furnace or pre-reduction with oxygen or electric steel plant.

Application of the above mentioned data to the design of an iron and steel complex basing on coal, coking or not, with a brief discussion of the case it should be desired to use charcoal.

Similar application to an iron and steel complex which would base on using liquid or gaseous hydrocarbons.

Last application to the case one would base an iron and steel complex on using electrical power.

Remarks about the expediency of dividing the iron and steel complex into an ore preparing works unit and a smelting and rolling one.

Interest of such an evolution for developing countries, as resulting of investments and industrial activities being transferred from highly developed countries to developing ones where there are iron ore deposits.

INTRODUCTION

The energy balance of iron and steel plants in the whole world took during the last years a course the nature of which is illustrated by means of some examples in Tables I and II. For the mean values by country as given there, one will note :

- first of all the steady decline of the quantities of energy consumed to produce a ton of raw steel ;
- then, further, the changes which took place in the distribution of this consumption among the various energy sources : there are substantially :
  - an increase on the consumption of electrical power and of liquid or gaseous fuels, and
  - a decrease of the consumptions of solid fuels and more specifically of coke (or coking coal fines)

It may be of interest, specially for iron and steel industrial projects in the developing areas, to discuss :

- at first the limits down to which these consumptions are able to be brought ;
- and further the distributions to be considered for these minimal consumptions among the various energy sources.

This last item is of special importance for developing countries, as many of them lack coking coals, but instead of that, they dispose of substantial amounts of coals of various qualities, of liquid or gaseous hydrocarbons and of electrical energy. We shall therefore successively consider the three cases where, owing to plentiful local resources, it is desired to base an iron and steel complex on :

- coal,
- liquid or gaseous hydrocarbons,
- electrical power.

Before discussing the three cases, we shall, in a first part, state the basic methods and assumptions of our following calculations.

To conclude this paper, we shall discuss in the last chapter the possibilities which, from an energetical point of view, would arise if the iron and steel complex, should be divided into a reduction or pre-reduction works unit on the one side and a smelting and rolling one on the other side.

In the following exemplifications, unlike Tables 1 and 2, we shall consider total requirements, including those needed by the coking plant, insofar as this is necessary.

One will find in APPENDIX 2 the equivalents we have assumed for the various energy supplies.

year	coal 6,7 th/kg	coke 7 th/kg	tar 9 th/kg	fuel-oil 10 th/kg	natural gas 9,4 th/m^3	coke gas 4,5 th/m^3	electricity 2,8 th/Kwh	TOTAL th (10^3kcal)
1966	74	4 565	27	640	90	243	1 294	6 953
1965	87	4 921	27	580	87	252	1 246	7 200
1964	107	5 068	27	590	86	275	1 215	7 368
1963	127	5 390	27	560	67	288	1 249	7 728
1962	147	5 565	27	460	90	306	1 193	7 788
1961	168	5 845	18	410	78	315	1 145	7 979
1960	221	5 873	27	390	56	306	1 117	7 990
1959	268	6 041	27	370	38	302	1 112	8 158
1958	315	6 104	36	390	3	302	1 092	8 242

TABLE 1 : Evolution of the total energy consumption (in thermies) per ton of raw steel, in mean value

- exemple for France - excluding coking plant.

Country	coal 6,7 th/kg	coke 7 th/kg	tar 9 th/kg	fuel-oil 10 th/kg	natural gas 9,4 th/m^3	coke gas 4,5 th/m^3	electricity 2,8 th/Kwh	TOTAL th (10^3kcal)
Fed. Rep. of Germany	302	36	3 661	779	349	590	1 072	6 789
Great Britain	315	4 235	162	1 630	-	466	1 207	8 015
France	74	4 585	27	540	90	243	1 294	6 953
Italy	34	2 198	?	770	476	279	1 772	5 529
Japan	88	2 604	?	1 100	?	144	1 240	5 176
U.S.S.R.	?	3 969	?	520	1 828	1 256	?	7 573
U.S.A.	415	3 262	90	440	1 011	698	966	6 882

TABLE 2 : Structural changes in the total energy consumption per ton of raw steel - for various countries - year 1966 - excluding coking plant.

I - CONTEMPLATED SCHEMES FOR THE VARIOUS IRON AND STEEL COMPLEXES

We shall at first recall the energy balances, as related to the ton of steel, which we shall use for the various cases to be reviewed below ; then, we shall consider the types of rolling mills that will serve to illustrate those various cases.

I. 1) ENERGY BALANCE FOR A WORKS INCLUDING BLAST FURNACE AND OXYGEN STEEL PLANT.

The progresses realized on the field of burden preparation and of blast-furnace technology are sufficiently well known for omitting to review them again. We shall content ourselves with restating data already obtained elsewhere (1) (2) and to recall the energy balances * relative to :

- a modern coking plant (Table 3) ;
- sintering (Table 4a) or pelletizing (Table 4b) of iron ores; the sintering will always be supposed to result in producing self-fluxing or basic sinters ;
- oxygen steelmaking (Table 5).

---

* Let us remind that Appendix 2 states the factors used to convert the various energetic supplies to thermies.

TABLE 3

BALANCE OF A COKING PLANT

related to a ton of coke for blast-furnace

	Inputs (thermies)	Outputs (thermies)
Coal with 28 % of volatile components 1 380 kg	10 300	
Coke > 20 mm 1 000 kg		7 000
Coke < 20 mm 63,5 kg		445
Tars 48 kg		430
Bensol 16,5 kg		165
Gas 325 m^3		2 350
Heating of furnaces	990	
Sensible heat of coke and by-products		592
Various needs and losses		308
	11 290	11 290
Various consumptions :		
- Electric power 35 KWh	98	
- Steam 102 kg	112	
- Processing of by-products	48	

Energy available as gas : 1 360 th higher calorific value

1 215 th lower calorific value

TABLE 4

Energy consumption for preparation of the burden

in thermies for one ton sifted self-fluxing sinter,

prepared from hematite ore

Table 4 a

Sintering

Solid fuel coke or coal-dust (*)	450	thermies
Igniting gas or fuel-oil	50	-
Electrical energy 35 KWh	98	-
Total :	598	-

Table 4 b

Pelletizing

Consumption for heating - fuel oil or gas -	250	thermies
Electrical energy 35 kWh -	98	-
Total :	348	-

N.B. The above stated consumptions do not involve any crushing operations that night occur.

(*) for instance 65 kg of coke-dust.

TABLE 5

Energy consumption in oxygen-steelworks

(in thermies per ton of steel)

	Data of material balance	Consumption in Thermies
Smelt iron	822 kg	
Scrap	260 kg	
Oxygen	48 m^3	121
Lime and dolomite	54 kg	72
Refractory lining	4 kg	7
Heating mixer		22
Various heatings		75
Electricity	30 kWh	84
Possible re-entry in the case of gases being captated without combustion.		381 130
	Net possible :	251

As the blast furnace is by far the most important apparatus from the point of view of energy, we shall consider in Table 6 a certain number of variants as follows :

1.- using sinters or pellets, or, to put it more exactly, a mixture of pellets, classified ores and basic sinters including all fluxes, prepared on grate ;

2.- same conditions as above with utilization of subsidiary fuel injection ;

3.- a variant involving overoxygenized blast and a high rate of injection, in conjunction with a high blast temperature (1 300°) and counter-pression ;

4.- another variant involving loading a certain amount of pre-reduced ores.

Starting from these 4 variants and adding the needs of the steelworks and those of burden preparation, one finds the total energy consumptions as stated in Table 7.

Taking into account both possibilities considered for the preparation of the burden, we come to 8 cases. With the utilization of products pre-reduced in the blast furnace, one is confronted with new possibilities of variation according to the selected processes. We have considered here only two of them : reduction by means of coal or of gases, therewith subdividing cases 4a and 4b into two sub-cases.

TABLE 6

Energy consumption in blast furnace - in thermies per ton of smelt iron

Variants as detailed in the text, p. 11 -

Variants (*)	1 reference	2 fuel-oil inject.	3 overoxygen. blast	4 pre-reduced burden
Coke	3 750	3 360	2 450	2 130
Fuel-oil	0	440	930	370
Blast heating	490	495	470	352
Blasting energy	204	210	224	148
Oxygen	0	0	112	0
Subsidiary needs	45	45	33	36
Total	4 489	4 550	4 219	3 036
Gas re-entry	1 360	1 436	1 190	880
Net consumption	3 129	3 114	3 029	2 156

(*)
Detailed balances of these four variants are given in Appendix 1, Tables A1, A2, A3 and A4.

TABLE 7

Total energy consumption for the **combinaison** blast **furnace** + oxygen steel plant in thermies per ton of steel-ingot.

Variants (*)	reference		fuel-oil injection		overoxygenized blast		pre-reduced burden **)	
	1 a	1 b	2 a	2 b	3 a	3 b	4 a	4 b
Burden preparation	736	429	736	429	736	429	340	198
Blast furnace (net)	2 571		2 560		2 490		1 840	
Steel plant (without recuperation)	381							
Total	3688	3381	3677	3370	3607	3300	2561	2419

**) excluding needs for preparation

a = sinters
b = pellets

Incorporating these **last needs,** one gets :

Pre-reduction in rotary kiln		Pre-reduction	
4 a/1	4 b/1	4 a/2	4 b/2
3 966	3 824	4 911	4 769

*) **Variants as** detailed in text, page 11

1a, 2a, 3a and 4a **correspond** to using sinter prepared on grate and

1b, 2b, 3b and 4b **correspond** to **pelletized sinter.**

I. 2) ENERGY BALANCE FOR A WORKS INCLUDING ELECTRIC IRONMAKING FURNACE AND OXYGEN STEEL PLANT

We consider two cases, the one corresponding to utilization of a well prepared oxidized burden and the other to utilizing a pre-reduced and preheated burden.

The present possibilities of the electric ironmaking furnace loaded with an oxidized burden and the impact of pre-reduction upon the operating data have been subjected to several investigations which allow to state with a good precision the attainable energy consumptions. For the sake of homogeneity, we convert the kWh into thermies basing on the requirements of a thermal power station. Indeed, in the case of the electric furnace, one could assume that it operater with hydraulically produced power and take into account its true thermal equivalence.

We assume for an oxidised burden consumptions of 350 kg coke and 2 000 kWh per ton of smelt iron; with a pre-reduced burden, we assume 110 kg coke and 650 kWh, supposing that the materials are being loaded hot into the furnace as they come from the reduction furnace.

For the pre-reduction, we assume that removing 80 % of the oxygen consumes 60 % of the energy which should be required for total reduction.

The energy balance of the oxygen steel plant will be the same as in the model described under 1.1). Under such conditions, one obtains for a ton of ingot steel the energy consumptions stated in the following Table 8.

TABLE 8

Energy consumptions for steel production by means of the combinaison

Electric reducing-furnace + oxygen plant

(in thermies per tons of ingot steel)

	1 Electric furnace with oxidized burden	2 Electric furnace with burden pre-reduced to 80 %
Burden preparation	736	1 680
Coke	2 010	630
Electrodes	56	56
Electric energy	4 600	1 495
Gas re-entry	880	285
Net total at smelt iron level	6 522	3 576
Steel plant	381	381
Total per ton of ingot	6 903	3 957
With hydraulically produced electric power	3 713	

I - 3) ENERGY BALANCE FOR A WORKS INCLUDING PRE-REDUCTION + ELECTRIC STEEL PLANT.

We consider now the case of the pre-reduction being carried up to a high degree on materials containing little gangue. One gets then an iron sponge which may be utilized directly in the electric steel making furnace. In a process of this king, one by-passes the smelt iron phase and consequently the step of oxygen steelmaking. The attainable results have been well ascertained by industrial experience or by experiments on pilot plant scale (3). It has been possible to state the consumption and production data of electric furnaces according to the kind of product being loaded, the size of furnaces and the way of operating them.

We shall restrict ourselves hare to giving an example consisting of using a product with 4 % gangue having still 3 % oxygen bound to the iron.

We consider two methods of obtaining this product, the first one making use of a rotary kiln and coal, the other being, by way of exemplification, the Hy L process, based on utilization of natural gas.

The burden of the electric furnace shall include 20 % of scrap ; therewith permitting to use the refuse of the plant. Table 9 shows the energy consumptions obtained per ton of ingot.

With the chosen kind of product and in a large capacity furnace, one may assume a consumption of 650 kWh/t of ingot steel. The gangue interferes non only through its quantity, but also through its basicity. An acid gangue which shall need to be neutralized impairs the consumption more than a neutral one.

TABLE 9

Electric energy consumption for steel production by the combinaison pre-reduction + electric furnace

(in thermies per ton of ingot steel)

	Rotary kiln reduction	Reduction in reactor type HyL
Pre-reduction of burden (840 kg Fe)	2 860	5 460
Electric furnace		
Carbon (24 kg)	168	168
Limestone (25 kg)	33	33
Oxygen (5 m^3)	13	13
Electric energy (650 kWh)	1 820	1 820
	4 894 Th.	7 494 Thermies

1 - 4) ENERGY CONSUMPTION OF ROLLING MILLS

Although we cannot discuss all possible cases, we shall state, by way of example, the energy consumptions which can be estimated for the four following cases :

- rolling train for merchant steel products with a capacity of the order of 300 000 t/year, supplied with billets from continuous casting,
- double-plate rolling train with a capacity of 400 000 t/year,
- steel strip train with a maximal capacity of 4 million tons per year supplied with slabs from a conventional casting installation,
- steel strip train of the same kind as the former one followed by a cold rolling shop with completing facilities to obtain thin sheets for tin production.

These four examples are treated in Table 10. They show that the energy requirements are largely divergent depending on the type of finished product which is wanted. The more and more progressing automation and mechanization of all operations are leading to an increase of electric power requirements. Increasing the rate of utilization of rolling mills by means of reducing the idling times and increasing the power factor contributes on the opposite to a substantial decrease of the electric consumptions. A better control of heating furnaces results also in lowering thermal requirements.

One will get an idea of the progresses accomplished during the last decades by considering the consumption of a steam powered rolling mill given in Table 10e.

TABLE 10

Energy consumption of rolling, per ton of finished product

10 a - Rolling train for merchant steel products,
supplied with billets from continuous casting
(relative output 1/1,060)

Reheating	475	Thermies
Rolling 80 kWh/t rolled	238	-
Handling 5 kWh/t	15	-
Water 15 m^3 (= 4,4 kWh)	13	-
	741	-

10 b - double plate rolling train

We shall assume it to be supplied with slabs

1 - relative output 1/1,120 up to 10 mm

2 - relative output 1/1,250 above 10 mm
one sheet only obtained from a slab

	1	2
Reheating	530	660
Rolling handling and shearing	232 (83 kWh)	382 (136 kWh)
Circulated water	22 (26 m^3)	38 (45 m^3)
	784 Thermies	1 080 Thermies

10 c - broad stripe train -
rolled from slab - shearing into sheets -
(relative output 1/1,180)

Reheating	540
Rolling, shearing, handling, 90 kWh	250
Water 42 m^3	35
	825 Thermies

TABLE 10 (continued)

10 d - Continuous strip rolling train and cold rolling shop for thin sheets to be tinned

rolled from 1 220

Reheatings, annealings	850
Electrical energy - 270 kWh	755
Steam 200 kg	200
Water 60 m^3	50
	1 855 Thermies

10 e - 10 mm thick sheets - Steam powered rolling mill - r

relative output 1/1,250

Reheating	700 Thermies
Rolling - 1 400 kg steam	1 540
Shearing - 40 kg steam	44
Water - 20 m^3 - 60 kg steam	66
	2 350 Thermies

The steam is taken from the boiler assuming a loss of 15 % in the distribution piping system.

II. ENERGY BALANCE OF AN IRON AND STEEL

COMPLEX BASING ON COAL

II. 1) CONSIDERED CASES

Among the energy supplies available in the world, the coal under its various forms occupies an important place. We shall therefore discuss here the possibilities which are available if it is desired to found an iron and steel complex basing mainly on this kind of energy.

Indeed, one has to distinguish between several cases according to the exact nature of the available fuel.

At first, one may have to do with a so called coking coal, it is then possible to adopt the model of conventional steelmaking, i.e. blast furnace and oxygen plant.

If, on the contrary, there is an abundant supply of no coking coal, such as for instance using the blast-furnace is excluded, but one may still rely on direct reduction processes in rotary kiln.

At last, one may dispose only of charcoal, either because of the existence of abundant forests or if it is possible to set eucalyptus plantations. This case occurs chiefly when no sources of energy of any kind are to be found on the spot.

The remain within the frame of approved commercial processes, one may also consider here the blast furnace followed by a steel-works.

We have finally three possible cases, two of which are very closely related in their principle, although they differ in the capacity of the plants that may be realized.

To those cases, we shall add the case of the conventional electric ironmaking furnace which consumes more electrical energy than solid fuels. It may be assumed either that apart from the coal, one disposes of hydraulically produced power, or that it is possible to get electrical energy for a reasonably low price in a thermal power station fired by no coking coal fines. For the electric furnace, there is no need of a coke of the metallurgical type, chiefly characterized by a good mechanical strength, but on the opposite, one looks for a highly reactive coke which, as a rule, is rather brittle. Coking processes like the continuous grate process give products which are satisfactory from this point of view and some coals which would not permit to turn towards blast furnace coke production can find here an utilization. Thus, the electric ironmaking furnace provides an additional free choice parameter.

We shall now examine what is obtainable from the point of view of energy by selecting the one or the other of the above considered solutions. We shall consider, by way of exemplification, the case of a works producing 300 000 t of steel sold as merchant steel products.

II. 2) BALANCES OF MATERIALS AND ENERGY FOR A TON OF STEEL.

In a first step, we shall examine the balances up to the ton of ingot steel.

21. Conventional steelmaking - blast furnace and oxygen steel plant.

We have stated in the first part the basic consumptions we assume. For a works producing 300 000 t/year, it is obvious that we are not in the ideal case as viewed from the point of view of the size of apparatuses. The blast furnace and the oxygen of at least 600 000 t/year. As for the energy consumptions, one may assume that they are not altered by this little size of the works, but to attain them, one must realize a very good operation. We shall suppose that continuous casting facilities are at hand and assume the following relative inputs :

- 1,06 t liquid steel for 1 ton of billet,
- 1,06 t of billets for 1 ton of merchant steel

products, i.e. finally 1,12 t liquid steel for 1 t of merchant steel products.

The following Table 11 a gives the elements of materials balance for a ton final steel.

TABLE 11-a

Elements of materials balance blast furnace + oxygen steelworks - Thermies per 1,12 t of steel (i.e. for a ton of commercial steel bars).

variants	1 reference	2 fuel-oil injection
coking plant coal - kg	678	610
coal for agglomeration completing the dust kg	58,0	61,0
fuel-oil - kg		41,5
Available gas from coking plant - thermies	598	537
Available gas from blast furnace - thermies	1 250	1 320

With regard to the small size of the works, we do consider only the use of sintered ore and only variants 1 and 2 for the blast furnace.

- 1 - agglomerated burden - without injection -

- 2 - with fuel oil injection -

For the energy consumptions, one comes to the balance of the following table 11-b.

TABLE 11-b

Energy consumption - combination blast furnace + oxygen steel plant - in thermies - for 1,12 t of steel (i.e. 1 ton of commercial steel bars)

variant	1 (reference)		2 (fuel-oil injection)	
coke	3 455		3 095	
sintering coal	401		424	
sintering coke breeze	219		196	
fuel-oil			405	
coking plant gas	598		537	
Steel obtained (values of Table 7, multiplied by 1,12		4 140		4 120
	4 673	4 140	4 657	4 120
Excess	533		537	

In such a plant, the energy supplies are made up of the coking coal and the coal needed for sintering. The gas from the coking plant and the gas from the blast furnace provide the possibility of producing the required electrical energy and, at steels level, there remains still an excess of a little more than 500 thermies.

2 - 2. No coking coal - Reduction in rotary kiln.

If one disposes of coal, but if this one is not fit for the production of a coke suitable for the blast furnace, a possible way of obtaining steel consists of accomplishing a reduction in a rotary kiln followed by a smelting in an electric furnace. Several reduction processes in rotary kiln permit to use solid fuels (anthracite, lignite, etc.) and have been developed during the last years. One may mention, for example, the SL/RN or Krupp processes.

As in the previously considered case, it requires 1,12 t of liquid steel to get a ton of commercial rolled product. In the steel production, one uses 900 kg of reduced iron per ton of steel, the rest being made up of scraps proceeding from refuses of the works.

Assuming an iron sponge with a 2 % oxygen content and 3 % gangue, one may anticipate the operating data shown in tables 12a and 12b.

TABLE 12-a

Elements of materials balance. Rotary kiln
and electric steelworks
in thermies for 1,12 t of steel (i.e. 1t of commercial rolled products)

Coal for pre-reduction	675 kg as lignite or 495 kg as coal
Carbon in electric furnace	16 kg
Electrical energy	780 kWh, equivalent to 310 kg coal or 430 kg lignite

TABLE 12-b

Energy balance - Rotary kiln and electric steel plant

in thermies for 1,12 t of steel (i.e. 1 t of commercial rolled products)

	Inputs	Outputs
Coal or lignite	5 580	
Steel obtained		5 580

Excess : nil

2.3. Utilization of charcoal

Il there are on the spot no energy supplies enabling to effect the reduction of the iron ore, and if the conditions are favourable, one may think to eucalyptus plantations to provide charcoal, especially in tropical regions.

Under such conditions, using a blast furnace supplied with charcoal and using the same fuel for the sintering, one may now obtain the following operating results (Tables 13a, b and c).

TABLE 13.a

Energy consumption for producing smelt iron - with charcoal, in thermies per ton of smelt iron.

Burden preparation	957 Thermies
Charcoal for blast furnace 620 kg	3 800
Blast heating - 1 000° C	490
Blasting energy	180
Subsidaries	40
	5 467
Gas return	1 340
Net consumption	4 127

TABLE 13-b

Elements of materials balance - blast furnace with charcoal and oxygen steel plant (for 1,12 t of steel, i.e. 1 t of commercial rolled products).

Charcoal for sintering	110 kg
Charcoal for blast furnace	570 kg
Gas available from blast furnace	1 230 Thermies

TABLE 13-c

Energy balance - gas furnace with charcoal in thermies for 1,12 t of steel (i.e. 1 t of commercial rolled products).

	Inputs	Outputs
Charcoal	4 100	
Steel iron production		3 800
Steel plant		428
	4 140	4 228
Deficit :	88	

2 - 4 - Electric ironmaking furnace -

A we have already mentionned it, this case may be of interest under certain circumstances.

One may assume the availability, apart from the coal, of hydraulically generated electric power ; we shall then take the real thermal equivalent of the kWh. One can also consider establishing a thermal power station supplied with coal or residues of its winning.

Depending on the cost of the kWh, it will be advantageous or not to effect a pre-reduction of the burden (3) (4). This is a hypothesis which we shall also take into consideration.

The elements of materials balance corresponding to these various possibilities are shown in the following Table 14 a.

The energy consumptions resulting therefrom are given in Table 14 b.

One will see in this Table energy surpluses which may be considered as fictitious in the case of using thermally generated electrical energie, for they correspond to gases which are not utilized, while they could replace coal in the power station.

TABLE 14 a : Electric ironmaking furnace + oxygen steelworks - elements of materials balance relative to 1,12 t of steel (i.e. 1 t of commercial rolled products).

	Oxidized burden		pre-reduced burden	
	kWh therm	kWh hydr	kWh therm	kWh hydr
coal for coke	444	444	139	139
coal for pre-reduction and burden preparation	88	82	239	239
coal for thermal power station	798	-	300	-
available gas th.	1 365	1 365	407	407

TABLE 14 b : Electric ironmaking furnace + oxygen steel plant energy consumptions for 1,12 t of steel (i.e. 1 ton of commercial rolled products.

	Oxidized burden				pre-reduced burden			
	kWh therm		kWh hydr		kWh therm		kWh hydr	
	I	O	I	O	I	O	I	O
coal	9 300		3 720		4 750		2 650	
hydraulic electricity			1 660				[illegible]	
steel elaboration (see tabl. 8)		7 750		3 980		4 440		3 100
	9 300	7 750	5 380	3 980	4 750	4 440	3 228	3 100
excess :	1 550		1 400		310		138	

I = input

O = output

II. 3) ENERGY BALANCE OF COMPLETE WORKS

We have just seen which energy and coal consumptions were required to obtain 1,12 t of steel according to various production schemes.

It is interesting to assess the result for the works as a whole, wherefore it is necessary to select a determined finished product.

Taking the assumption of a works producing 500 000 t/year, the merchant rolled steel is incontestably the type of product most fitting to the size of the works and to a developing country.

In this case, one disposes, after the steel making plant of continuous casting facilities and of a rolling mill for merchant steel products.

To the specific consumptions as previously ascertained, it is fair to add the requirements of the continuous casting as well as those of rolling and finishing.

For the continuous casting, we shall assume 3 m^3 of oxygen and 10 kWh per ton of billet, that is a total equivalent of 13,5 kWh per ton of final product.

The requirements of rolling are those given by Table 10a in the first part of this paper, i.e. 741 thermies or 475 thermies more 89,5 kWh.

Assuming that the electric power is of thermal origin, the total requirements after the steelmaking plant amount to 779 thermies, comparable to the available surplus at liquid steel level.

The following Table 15 shows the results obtained in the four cases that have been considered.

We have assumed the possibility of recovering the energy surplus and of making up for the deficit by making complemental use of coal.

TABLE 15 : energy consumptions for a ton of merchant rolled products.

variant	Bl. Furn. + Oxy. Steel Plant		Direct. reduct. and electric furn.	Bl. F. charcoal + O_2 steel plant	Electric iron-making furnace + oxygen steel plant	
	refer.	fuel-oil inject.				prereduced load
total energy consumption	4 919	4 899	6 359	5 007	8 529	5 219
available surplus th.					771	
deficit in th., or in kg coal	246 35	242 34,4	779 111	667 142	 0	469 67
total coal consumption (7 th/kg)	771	695,4	934	822	1 330	745
fuel-oil - kg		41,5				

(*) It is here charcoal with 77 % carbon constant that is being considered

The annual fuel consumptions in form of coal for the 500 000 t/year works capacity correspond to the data of the following Table 16.

TABLE 16 : coal consumption of the works in thousands of tons per year.

Blast furnace		Direct reduction and electric smelting	Charcoal	Electric ironmaking furnace	
				oxidized burden	pre-reduced burden
231	209	280	246,5	399	223

It is interesting to note that the results of the electric ironmaking furnace using pre-reduced burdens are equivalent to those of the blast furnace. Utilization of oxidized burden, if one does not dispose of hydraulically produced electric power, may be advocated only in very particular contexts.

In the case of existing hydraulic supplies, one may also consider the solution of the second case ; then, the coal requirements are cut by about 340 kg per ton of end product, i.e. about 100 t/year. However, this solution is te be compared to the electric ironmaking furnace which leads to a coal consumption of 470 kg per ton of rolled product, i.e. 140 000 t/year while requiring a coke production which on the other hand do not demand a conventional coking plant.

III - ENERGY BALANCE OF AN IRON AND STEEL COMPLEX BASING ON LIQUID OR GASEOUS HYDROCARBONS.

III - 1. CASES CONSIDERED.

In many countries which do not dispose of an iron and steel industry, while having iron ore supplies, liquid or gaseous hydrocarbons are available.

In contexts of this kind, the processes which enable to obtain steel by using these sources of energy must be taken into account. The general model that may be considered comprises producing an iron sponge which subsequently will be smelt in a suitable apparatus.

Among these, the electric furnace is surely the most conventional, but it is also possible to consider using apparatuses of the rotary kiln type, such as is the case with the BOUCHET process, thereby allowing to replace electrical energy by a hydrocarbon (5).

Among the possible reduction processes, one finds all the processes turning to use of fluid beds and those using a shaft furnace. Numerous pilot plants exist or are being erected, but the Hy L process is the only one to be able to pride itself of an important commercial experience.

In this paper, in which we endeavour chiefly to give examples of possible energy consumptions, we shall consider only this process. We dispose there of actually attained values.

We shall therefore discuss in this chapter two schemes of steel production using the same pre-reduction process, but differing in the smelting step, the one basing upon the electric furnace and the other on a rotary kiln heated by a hydrocarbon - oxygen burner.

As in Chapter II, we take the case of a works producing only bar and shaped products with a relative input of 1,12 ton liquid steel per ton of end product.

If considering a plant of higher capacity, it would be possible to revert to the conventional iron and steel manufacturing process using blast furnace and oxygen steel plant. For the blast furnace, one should adopt an operation with over-oxygenated blast and injection of important quantities of hydrocarbons, a type of operation we have already discussed in Chapter I. However, this solution requires the utilization of relatively important quantities of coke, as may be seen on Fig. 4.

III - 2. ENERGY CONSUMPTION PER TON OF STEEL.

2. 1. Production of iron sponge.

The elements of the materials balance and the resulting energy consumptions are given in the following Table 17 a.

The energy consumptions of the Hy L process may appear high, but as a matter of fact, taking into account the price of natural gas, it has not been tried to lower them. In a less favourable utilization context, it would be possible to reduce substantiably the needs.

TABLE 17 a : Energy consumption for 1 ton of iron sponge - Hy L process - residual oxygen 4 %.

	elements of materials balance	energy consumption th.
natural gas	710 m^3	5 680
electricity	30 kWh	84
		5 764

2.2. Smelting in electric arc furnace.

In conventional commercial practice, one will use electric power to achieve smelting of the iron sponge.

This energy is produced in a thermal power station supplied with hydrocarbons.

As far as there is no other source of electricity available and it is therefore necessary to erect a thermal power station, the electric smelting furnace is the alluring solution inasmuch as it is of interest to provide a power station of important capacity.

With an iron sponge having a 4 % oxygen content and 2 % gangue, il will be consumed for a ton of steel 720 kWh and 40 kg carbon, i.e. a total of 2 300 thermies.

875 kg of iron are loaded in form of sponge and the rest is made up with scrap originating substantially from the works, the subsidiary supply from the exterior being assumed to be extremely small.

In such a case where one shoud dispose of a high capacity power station, the kWh should be produced more cheaply.

A total requirement of 2 060 thermies should be more realistic.

For a ton of end product, one comes thus to an energy consumption of 7 980 thermies used for elaborating the liquid steel.

2.3. Smelting in rotary kiln.

Using a rotary kiln for the smelting, as in the BOUCHET process (5) makes it possible to use directly in a burner a big part of the hydrocarbon, the electrical energy being used only for oxygen production and in various applications of little importance.

This solution may in some cases allow to dispense with investing in a power station and moreover, it leads to a smaller thermal consumption.

Table 17 b gives the attainable consumption values :

TABLE 17 b : Smelting of reduced products in rotary kiln - balance in thermies per ton of steel.

	data of materials balance	consumption thermies
carbon	75 kg	590
natural gas	55 m^3	440
oxygen	180 m^3	450
electrical energy	50 kWh	140
		1 580

Of course, the scrap produced in the works is recycled with the iron sponge. For the sake of homogeneity, we have kept the same values as in the case of electric furnace operation.

For a ton of end product, consequently, one consumes up to the production of liquid steel : 7 450 thermies.

III - 3. TOTAL CONSUMPTIONS PER TON OF ROLLED PRODUCT.

Still placing ourselves in the frame of a works producing 300 000 t/year of bar and shaped products, one disposes after the steel smelting plant of a continuous casting plant and of a rolling train for merchant steel products.

As we saw it the previous chapter, these installations require a consumption, under various forms, of 780 thermies per ton of merchant product.

The total requirements of the work amount therwith to 8 760 thermies per ton sold in the case of an electric steelmaking plant and to 8 230 thermies in the case of a smelting in rotary kiln.

Assuming a natural gas with a heat value of 8 thermies/m^3, as we have supposed up to now while taking the mexican exemplification, the requirements of the works will be, in millions of m^3, 328 in one case and 307 in the other. To these gas requirements, one must add in the first case 13 500 t of carbon and 1 500 to 2 000 t of electrodes, and in the second case 25 500 tons of carbon.

IV - ENERGY BALANCE OF AN IRON AND STEEL COMPLEX BASING ON ELECTRICAL ENERGY

Whatever schemes are contemplated for steel production, all of them involve a certain amount of electrical energy.

When using electric furnaces, the part of this energy increases highly and plays a decisive role in selecting the pattern of the works.

One may dispose of hydraulically produced electric power, have a surplus thermal power station or dispose of poor fuels which can nevertheless be used to supply an suitable power station. In all such cases, it is of interest to take into consideration the metallurgical schemes which grant a big place to the electrical energy.

All of them have been reviewed in the previous chapters, whereas the accent was put on other energy supplies.

Two kinds of processes can be made out : those using an electric furnace reduction and those using an electric arc furnace more specially appointed to smelting and refining operations.

In the first kind of processes, one finds again :

- the conventional electric ironmaking furnace, supplied with oxidized burdens
- the electric smelting furnace supplied with pre-reduced and pre-heated burdens.

In the examplification of Chapter 2, we have considered the reduction with coal which corresponds to the present projects or realizations. As a matter of fact, it would be as well possible to use a pre-reduction by means of gases.

The second kind of processes includes all the combinations involving a high degree of pre-reduction of the ore and smelting of the iron sponge in an electric furnace.

Among all the possible combinations, we have examined two cases using as a reducing means carbon for the one and gas for the other.

The following Table 18 summarizes all the obtained results, while setting off the kWh requirements.

From a purely energetical point of view, the balance favours the electric ironmaking furnace, but this solution implies an oxygen steel plant.

TABLE 18 : Energy consumption per t of commercial product - Processes using an important part of electrical energy.

processes	kWh consumption	energy consumption over and above - thermies
Electric ironmaking furnace		
- oxidized burden	2 060	2 000
- burden pre-reduced to 80 % and preheated	870	2 780
Electric steelmaking furnace		
- pre-reduced burden O_2 = 2 %, gangue = 3 %	883	3 880
- pre-reduction by means of coal		
- pre-reduced burden O_2 = 4 % - gangue = 3 %	935	6 140
pre-reduction by means of gases		

V - EXPEDIENCY OF DIVIDING THE IRON AND STEEL COMPLEX INTO AN ORE PREPARATING UNIT AND A SMELTING AND ROLLING ONE

The conventional iron and steel industry using the blast furnace followed by an oxygen steel plant, and all the other schemes involving an intermediary smelt iron phase lead practically to the design of works processing the product from the ore stage to the rolled product. Although one is from now onward exporting pig iron, it is more natural to contemplate a partition at semi-finished product's level and, if one will separate at this point, to devise :

- an iron an steel works with ore preparation, coking plant, blast furnace, oxygen steelmaking plant and continuous or conventional casting in a developing country having abundant ore supplies (6).
- the transportation of semi-finished products, slabs or billets, by specially adapted means, specially by means of ships designed for such handlings (7),
- the rolling mills near the consumer centers, in industrialized areas.

From the energetical point of view, one comes to the division according Table 19 :

TABLE 19

Energy balance of the semi-products works (1,12 t of steel for 1 t of billets)

input	4 673	output :	steel,	4 140
			blooming and billets train	533
	4 673			4 673

Energy balance of the re-rolling works per ton of rolled products.

according to nature of products, from comprised of	740 to 1 855 thermies
fuels (substantielly liquid or gaseous ones) from	500 to 1 100 thermies
electrical energy	80 to 270 thermies

One will note that the gas surplus of the semi-products works is depending on the production program. According to the part of cold ingots being loaded into the pits, the thermal consumption will be more or less important. In the given exemplification, the energy flows of the works are balanced ; in fact one may assume, as the case may be, a slight energy deficit or surplus.

A scheme including pre-reduction followed by a smelting, on the opposite allows, to turn very easily (at least if the risks of re-oxidisation of the pre-reduced ore are avoided) two stages of production which may be geographically separated.

On may then contemplate pre-reduction works whose location can be dictated by the possibilities of ore and energy supply.

Il will be further possible to provide smelting and rolling works whose location will be were strongly influenced by the market of the end products.

This scheme may be applied as well inside the same country as in a group of contries far apart from each other.

One may also contemplate pre-reduction works of big production capacity intended to supply several smelting and rolling works.

The smelting and rolling works will often be able to be located on a coast, basing on electrical energy.

From the point of view of energy, the distributions is made according to the following Table 20.

TABLE 20

Energy balance of the pre-reduction works (per ton of pre-reduced iron)

a) reduction by coal in rotary kiln

480 - 500 kg coal
35 - 45 kWh making up 3 460 to 3 625 thermies

b) reduction by natural gas

710 m^3 of gas

30 kWh

making up 5 765 thermies

Energy balance of the smelting and rolling works

- per ton of billets (smelting + casting)
  2 100 to 2 300 thermies
- and then, for a ton of rolled product, according to the kind of products, between 740 and 1 855 thermies
  comprising 500 to 1 100 thermies as fuels
  and 80 to 270 kWh.

For a smelting works, on may consider that it is possible to supply it from a big thermal power plant, not exceding a consumption of 2,4 thermies per kWh. One comes this way to energy requirements lower than in Table 20 by 300 to 400 thermies as the case may be.

One sees by examining the Table 20 that the energy consumptions in the transforming works are cut by nearly the half. It becomes then possible to locate such works even in areas where only limited energy supplies are available.

CONCLUSIONS

The whole analysis made in this paper confirms very well the decreases of energy consumption per ton of raw or rolled steel, which have been ascertained on the national mean values. One has been able to seen down to which level it is easy to come for a ton of raw steel in the case of an integrated works producing merchant rolled products.

Let us remind, according to the values of Table 15, that one can attain, for such an integrated works, including the coking plant, about 4 900 thermies/ ton of rolled steel, i.e. hardly 4 400 thermies per ton of raw steel.

There are however several points to note :

- as is most clearly to be seen on Table 10, these consumptions will possibly be substantially different if the works produce different rolled products as for instance thin cold rolled sheets ;
- The situation, on the other hand, would be very different if, instead of an integrated works, one should contemplate works basing on scrap ;
- and lastly, the criterion of thermal consumption cannot be considered as a unique element of selection between various processes or various patterns of works.

Besides, we purposedly stress this last remark, for a high energy consumption may well be advocated if :

- it is relative to cheap and abundant energy supply,
- it leads, all calculations being made, to investments, and above all to costs, which are sufficiently low.

A second conclusion of the present analysis is that it is quite possible to contemplate, according to the available energy supplies, an iron and steel works with a capacity of a few thousands of tons yearly, which would rely for its energy supply :

- either on coal, coking or not, or charcoal, for 100 % of its requirements ;
- or on hydrocarbons (liquid or above all gaseous ones) for more than 95 % of its requirements (see Fig 5 and 6).
- or on electric energy, hydro-electric or nuclear for instance, but here, on can cover at best only 20 % of the requirements with this source of energy (see Fig 8).

We must at last insist on a third conclusion : with the progression of iron-ore mining in developing countries, one may contemplate a new extension of industrial activity in these areas. That would be the production of pre-reduced iron ores, in cases of pig iron or even of semi-finished products, slabs or billets.

To keep the point of view of energy, such prospects would lead to in important transfer of hydrocarbon consumptions or of coal from the industrialised areas to the developing countries.

While not intending to discuss thoroughly this matter which in itself would deserve a long analysis, we have purposedly tried to give a full picture of all these prospects.

BIBLIOGRAPHY

(1) A full series of data have been published on the occasion of the first symposium / of the United Nations in Prag: Interregional Symposium on the applications of modern technical practices in the iron and steel industry to developing countries" - November 11 th - 26 th 1963 -

and in Geneva : "Conférence des Nations-Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées" February 4 th - 20 th 1963 -

(2) J. ASTIER - J. MICHARD : "Les usages de l'énergie en sidérurgie" April 1968 - Revue Française de l'Energie -

(3) A lot of data on this matter have been presented in the Congress on production and utilization of pre-reduced ores, held in EVIAN, May 29 th to 31 th 1967.

(4) data about this point are published in the VIth International Congress of Electrothermice, BRIGHTON - May 13 th to 18 th 1968

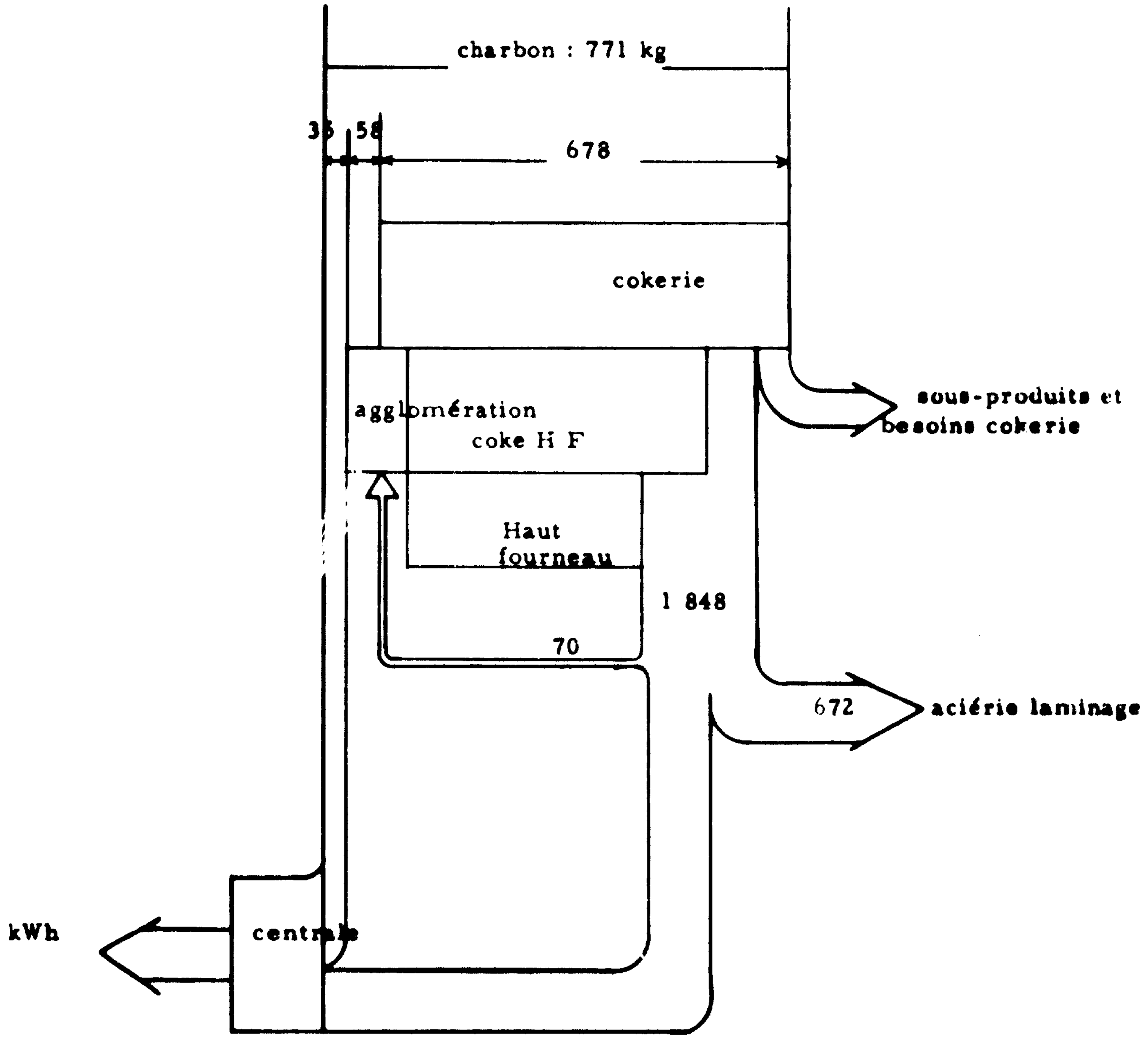
(5) see specially the communication of MM. ARCHER and J.L. GATELAIS to the EVIAN Congress (3).

(6) P.D. VELOSO - Perspectivas da participao brasileira no mercado internacional do aço (in portuguese) - communication to the XXIInd Congress of the A B M in VITORIA (Brasil) July 3 rd to 7 th 1967.

(7) Communication by Roland WASMUTH "Projeto de navio cargueiro especial para o transporte de semi-acabados de aço", also to the XXIInd Congress of the A B M.

Figure 1

Schematic diagram of the utilisation of energy in conventional iron and steel industry



charbon = coal

cokerie = coking plant

agglomeration, coke HF = agglomeration, coke BF

haut-fourneau = blast furnace

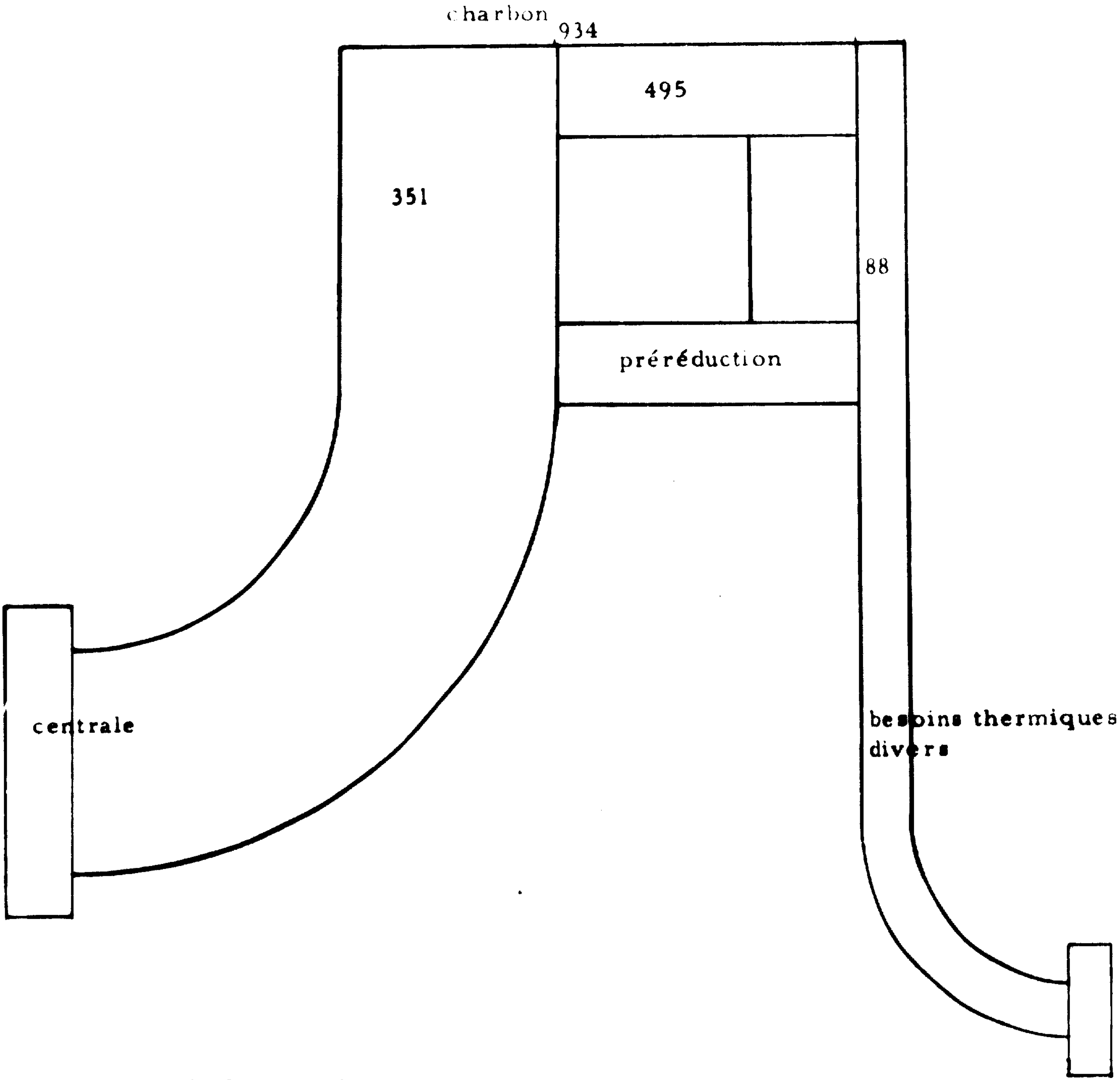
sous-produits et besoins cokerie = by-products and coking plant requirements

aciérie, laminage = steelmaking plant, rolling mill

centrale = power station

Figure 2

Schematic diagram of the utilization of energy in a combination rotary kiln electric steelmaking plant



charbon = coal

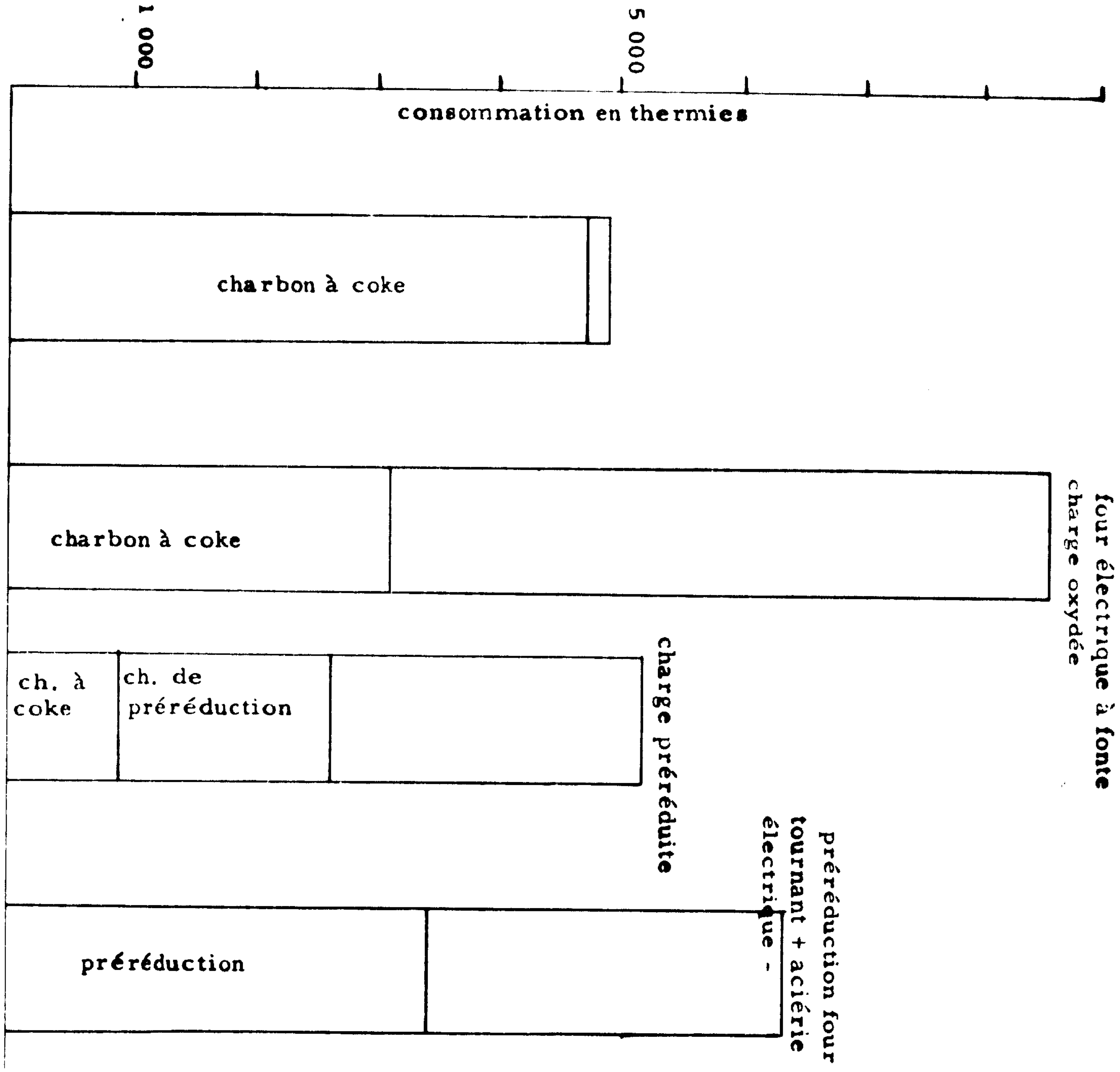
préréduction = pre-reduction

besoins thermiques divers = various thermal requirements

centrale = power station

Figure 3

Comparison of thermal consumptions of production schemes based on coal - consumption in thermies -



charbon à coke = coal for coke production

four électrique fonte) (= electric ironmaking furnace

charge oxydée) oxidized burden

ch. de **préréduction** = coal for pre-reduction

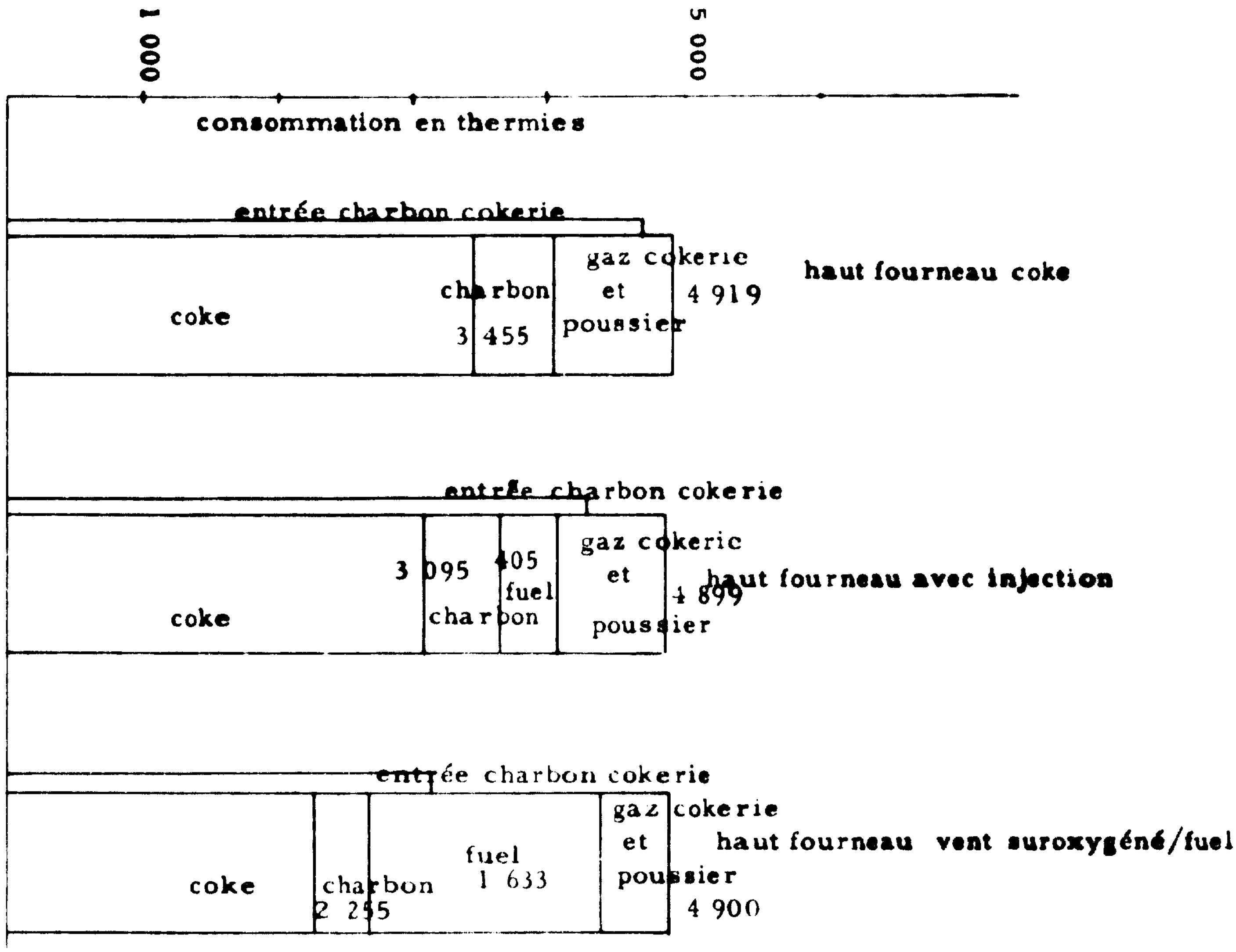
préréduction = pre-reduction

préréduction four tournant = pre-reduction in rotary **kiln**

+ **aciérie** électrique + electric **steel** plant

Figure 4

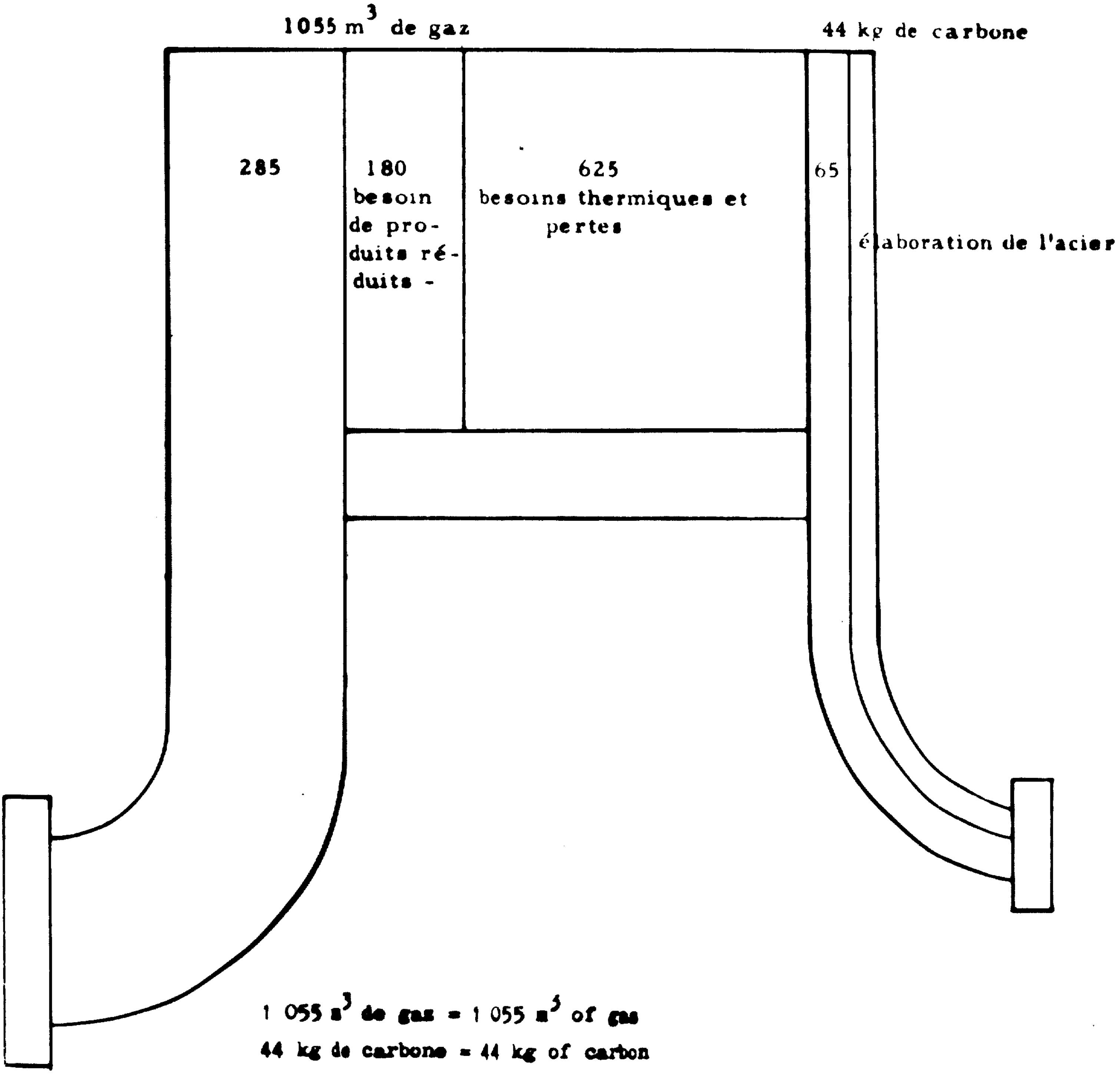
Distribution of thermal supplies for three cases of conventional works with blast furnace



consommation en thermies = consumption in thermies
entrée charbon cokerie = coal input coking plant
coke = coke
charbon = coal
gaz cokerie et poussier = gas from coking plant and coal dust
fuel = fuel-oil
haut-fourneau coke = blast furnace, coke
haut-fourneau avec injection = blast furnace with injection
haut-fourneau vent suroxygéné/fuel = blast furnace with over-oxygenated blast/ fuel-oil

Figure 5

Schematic diagram of the utilization of energy in a combination H y L + electric smelting furnace



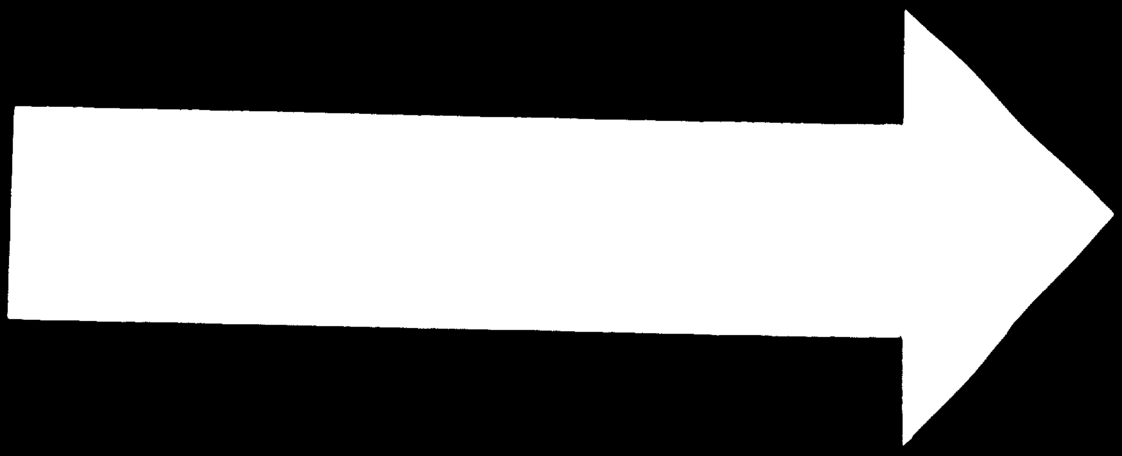
1 055 m^3 de gaz = 1 055 m^3 of gas

44 kg de carbone = 44 kg of carbon

besoin de produits réduits = reduced products requirement

besoins thermiques et pertes = heat requirements and losses

élaboration de l'acier = steel elaboration



74.10.15

2 OF 2

01331

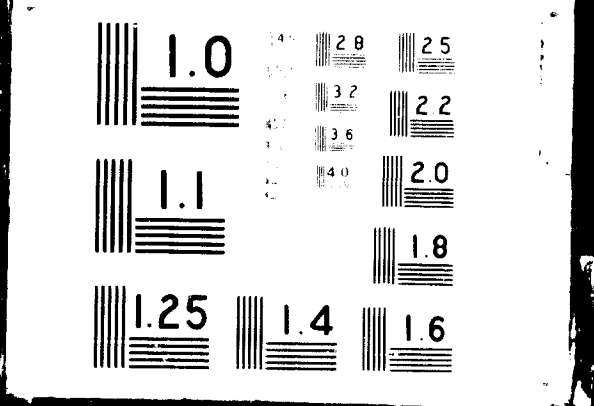
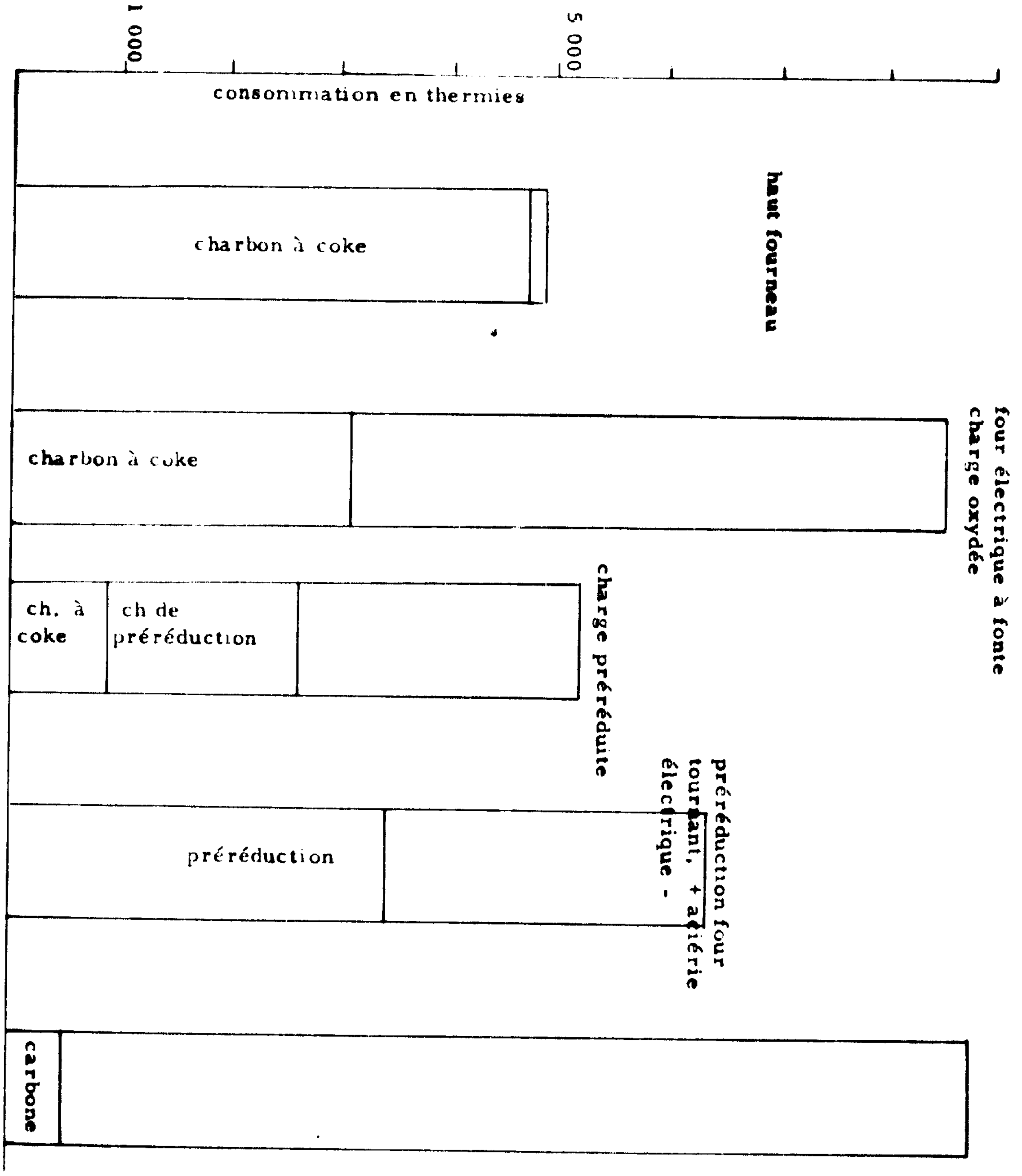


Figure 6

Comparison of thermal consumptions of the combination H y L + electric furnace with those of schemes based on coal

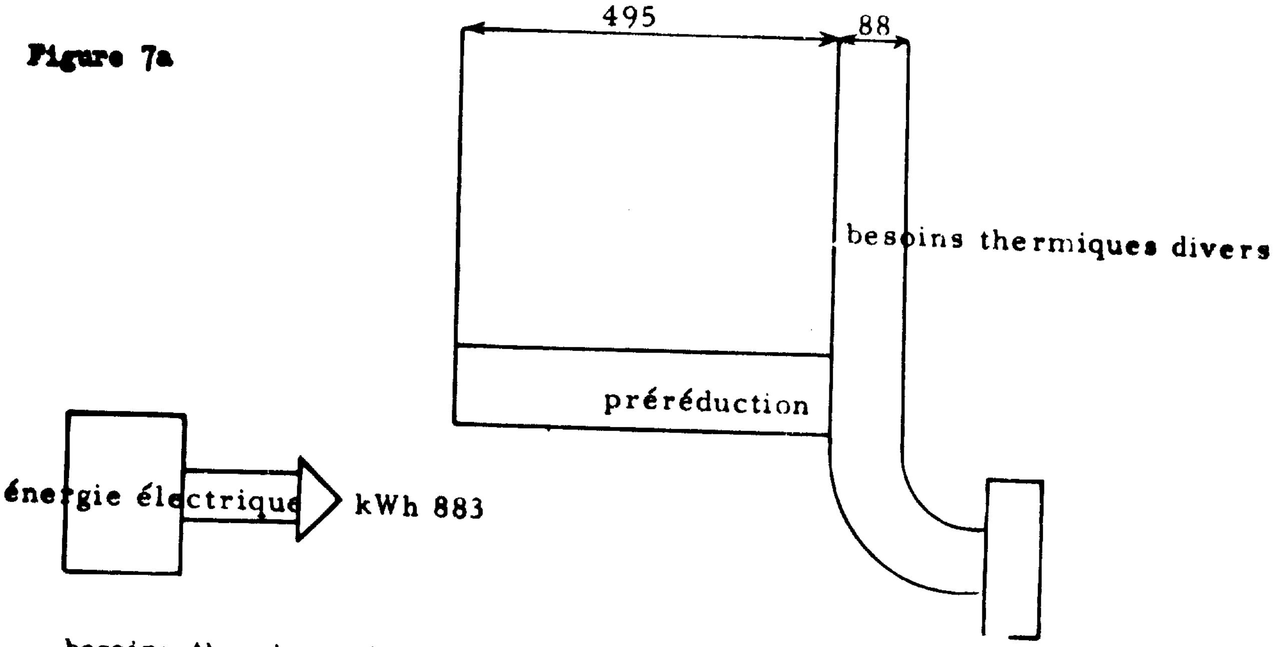


consommation en thermies = consumption in thermies
charbon à coke = coal for coke production
haut-fourneau = blast furnace
four électrique à fonte) = electric ironmaking furnace
charge oxydée) oxidized burden
ch. de préréduction = coal for pre-reduction
charge préréduite = pre-reduced burden
préréduction = pre-reduction
préréduction four tournant = pre-reduction in rotary kiln
+ aciérie électrique + electric steel plant

Figure 7

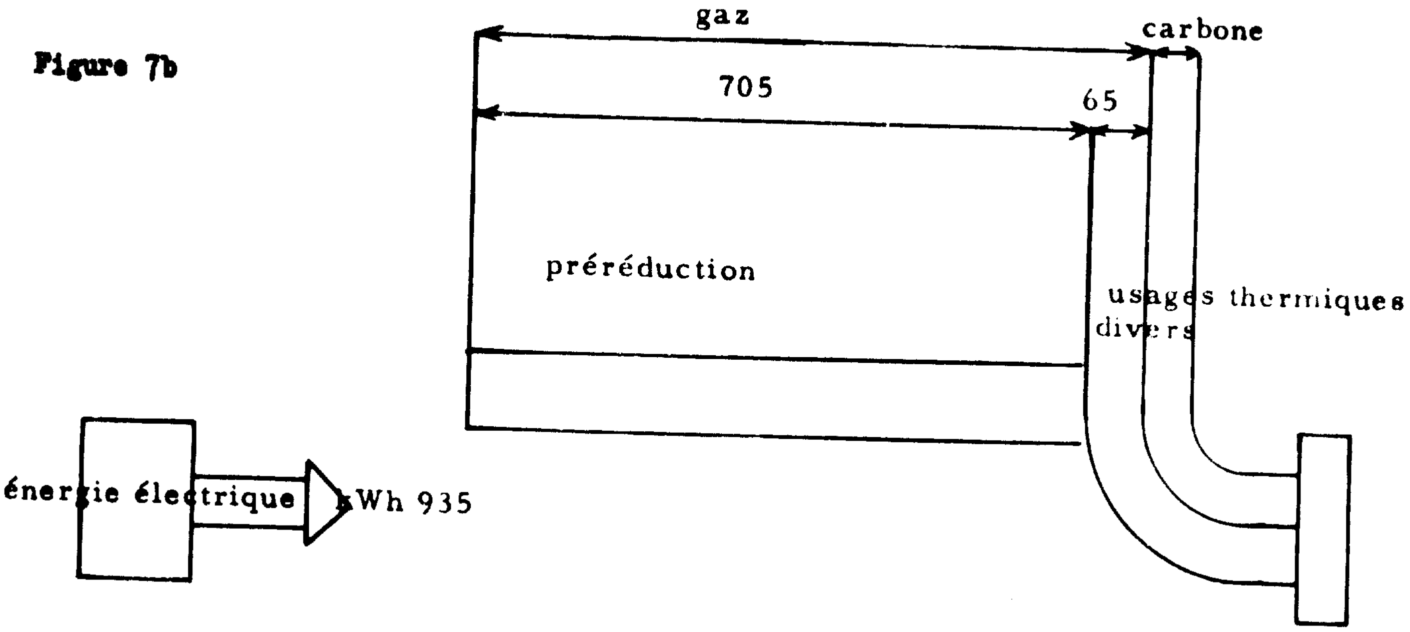
Schematic distribution of energy utilization in a combination pre-reduction + electric furnace with electrical energy supply from outside

Figure 7a



besoins thermiques divers = various thermal requirements
préréduction = pre-reduction
énergie électrique = electrical energy

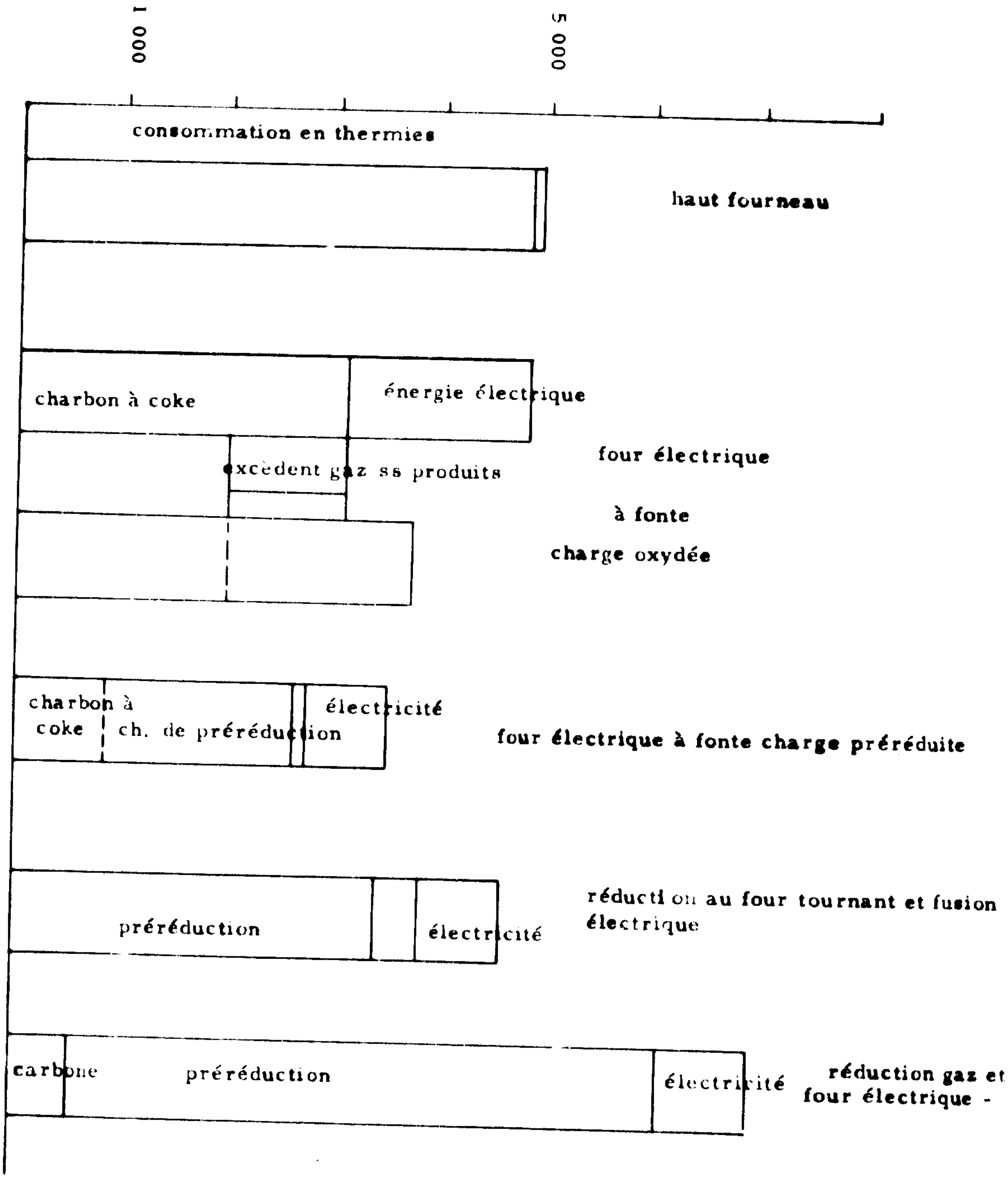
Figure 7b



gaz = gas
carbone = carbon
préréduction = pre-reduction
usages thermiques divers = various thermal uses
énergie électrique = electrical energy

Figure 8

Comparison of thermal consumptions of the various contemplated schemes with electrical energy supply from outside (kWh assumed for 0.86 useful thermy)



consommation en thermies = consumption in thermies
haut-fourneau = blast furnace
charbon à coke = coal for coke production
énergie électrique = electrical energy
excédent gaz s.s produits = gas surplus, by-products
four électrique à fonte = electric ironmaking furnace
charge oxydée oxidized burden
ch. de pré-réduction = coal for pre-reduction
électricité = electricity
four électrique à fonte = electric ironmaking furnace
charge préréduite pre-reduced burden
préréduction = pre-reduction
réduction au four tournant = reduction in rotary kiln
et fusion électrique and electric smelting
carbone = carbon
réduction gaz et four électrique = gas reduction and electric furnace

APPENDIX 1

TABLE A-1

DATA ABOUT BLAST FURNACES

Blast furnace loaded with agglomerated products,
operating on coke without injection

	Materials balance data	Thermies	kWh
Ore preparation storing and crushing			5
Agglomeration	1,5 t		
fuel and ignition		750	
electrical energy			40
Blast furnace			
coke	535	3 750	
Blast heating (1 000° C)			
steam - kg	30	30	
blasting	1 240 m^3	490	73
Subsidiaries			
cooling water			6
granulation water			3
purification of gases			5
loading			2
- gas re-entries - losses deducted	1 740 m^3	1 360	
Gross consumption		5 020	
Balance		3 660	
Effectively available thermies		870	

TABLE A-2

Blast furnace supplied with rich agglomerated ore

Hematite iron produced

	Consumption t/iron	Thermies	kWh
Ore preparation			
storing and crushing			5
Agglomeration	1,5 t		
fuel and ignition		750	
electrical energy			40
Blast furnace			
coke kg	480	3 360	
fuel-oil kg	45	440	
blast heating (1 000° C)	1 275 m^3	495	
steam kg	14	14	
blasting			75
Subsidiaries			
cooling water			6
granulation water			3
purification of gases			5
loading			2
- gas re-entries - losses deducted	1 760 m^3	1 436	
Gross consumption		5 049	
balance		3 613	136
Effectively available thermies in gas		931	

TABLE A-3

Blast furnace supplied with **agglomerated rich ore** - **using** high blast **temperatures** - **counter-pression** - oxygen - fuel-oil

	Consumption	**Thermies**	kWh
Burden preparation (with 40 % pellets)		750 (480)	47 (30)
Blast furnace			
coke	350	2 450	
fuel-oil	96	930	
blast heating (1 300° C)	892 m^3	470	
steam	10	10	
(*) oxygen	62 m^3		40
blasting			80(**
Subsidiaries			
cooling water			4
granulation			3
purification			3
loading			2
- gas re-entries losses deducted	1 460 m^3	1 190	179
Gross consumption		4 610	
Balance		3 420	
Effectively available thermies in gas		720	

(*) The oxygen used is assumed to have a purity of 70 %.
The energy part related to pure oxygen can be evaluated to 0,65 kWh/ Nm^3 O_2 by equivalent.

(**) Counter pression 1,2 kg/m^2 - Through recuperation of expansion energy of the mouth-gases, one could dispose of 50 kWh.

TABLE A-4

Energy consumption for smelt iron production
Addition of pre-reduced products to the burden

	Data of Materials balance	Thermies	kWh
Burden preparation		405	24
Blast furnace			
metallic iron in burden	407		
coke	304	2 130	
fuel-oil	38	370	
blast heating (1 000° C)	910 m^3	352	
blasting			53
Subsidiaries			
cooling water			4,5
granulation water			3
purification of gases			3,5
loading			2
- gas re-entries losses deducted	1 290 m^3	900	
Gross consumption		3 257	90
Balance		2 357	90
Effectively available thermies in gas		548	

APPENDIX 2

ASSUMED EQUIVALENTS

We have assumed * the following equivalents :

1 kg coal = 7 thermies

1 kg coke = 7 thermies

1 kg lignite = 5,1 thermies

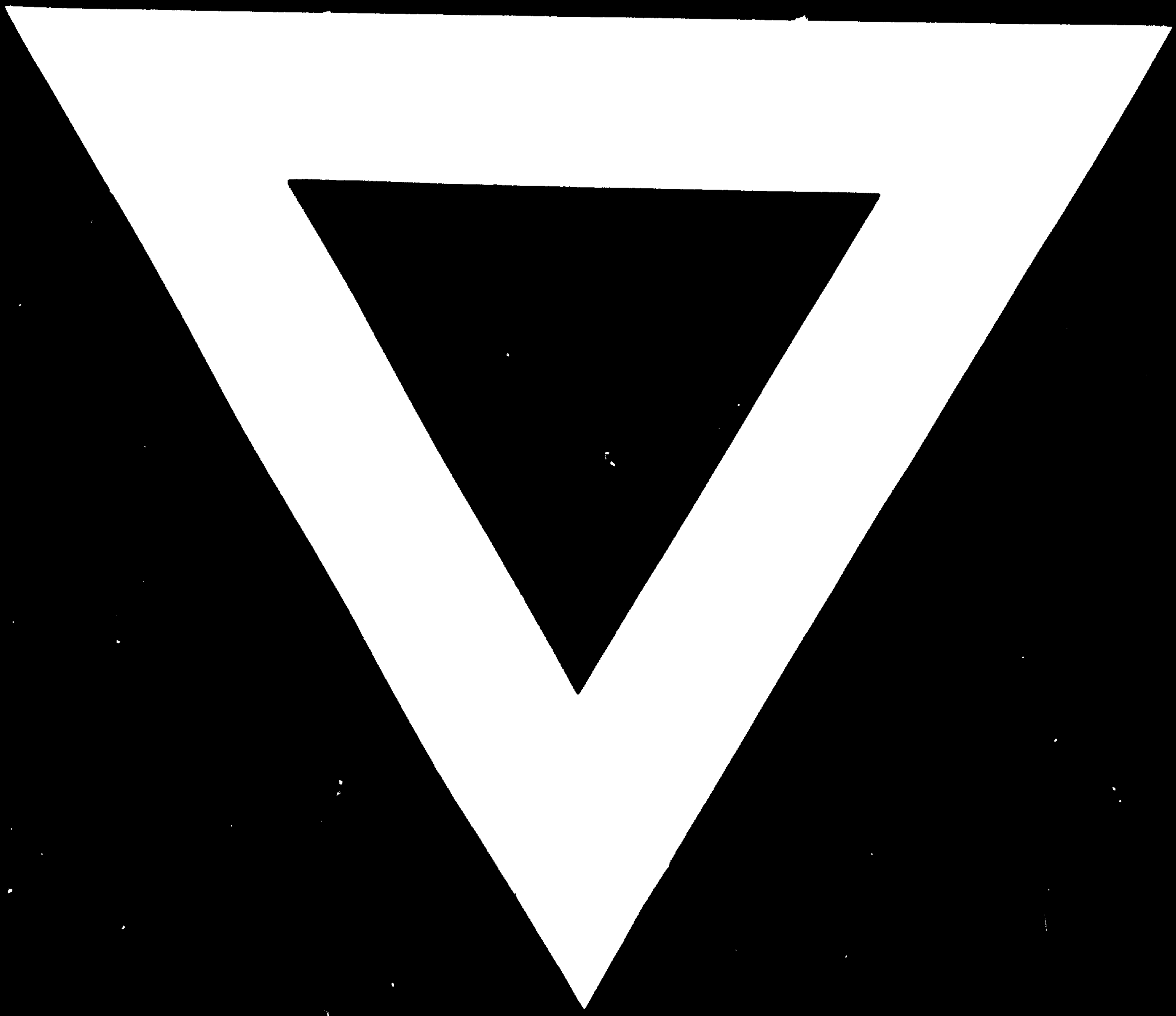
1 kWh = 2,8 thermies

1 m^3 natural gas = 8 thermies

1 kg fuel-oil = 9,5 thermies

1 m^3 oxygen = 0,9 kWh

* except when otherwise staded (especially Tables I and II)



74.10.15