UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

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19827

Workshop on Steel Plant and Rolling Mill Rehabilitation

Nairobi, Kenya, 15 - 18 July 1991

ANNEX 13 of the

# PROCEEDINGS*

Consideration of technological questions related to the rehabilitation process and maintenance of steel plants/rolling mills

Presentation by UNIDO Consultants


Messrs. Richer and Scherrer

Voest-Alpine, Austria


June 1992

* Mention of company names and commercial products does not imply the endorsement of UNIDO.

This document has not been edited.

# UNIDO WORKSHOP

## Aspects of Rehabilitation Programmes

(based on experiences gained during execution of a plant improvement plan at RolMill Kenya)

Presented by: Dr. Richter, Dipl. Ing. Scherrer

## 1. RolMill Kenya-Rehabilitation Project

1.1 Project Bases and Project Development

1.2 Presentation of Project Highlights/Results

## 2. Technological Aspects of Improvement-Programme at EAF-Plants

2.1 Review of EAF-Technology Development (improvement potentials for savings and production increase)

2.2 Scrap Preparation

## 3. Role of Technical Services for Steel Plants & Rolling Mills

3.1 General Considerations and Maintenance Strategies

3.2 Reheating Furnace Improvement; Example of Activities of Technical Services

3.3 Cooling Water Circuits

3.4 Electrical Power Supply

## 4. Results and Improvement Potential RolMil Kenya

# 1. RolMil Kenya Rehabilitation Project

## 1.1 Project Bases and Development

# ACTION PLAN

**(TIMETABLE)**

**1986** - UNIDO experts prepared reports on the condition of iron and steel industries in the PTA region

Selection of ROLMIL Kenya for the Rehabilitation Programme

**1989** - 08-22 - 09-4
Fact Finding Mission (2 experts)

Elaboration of an Action Plan

Technical support from Home Office

Specification of equipment and tools, purchase and supply to Nairobi

**1990** - 05-29 - 06-08
On-the-Job Training of a ROLMIL metallurgist in Austria

09-18 - 12-14
Technical Assistance phase (5 experts)

**1991** - Continued Technical Support from Home Office

05-23
Final Report

## GENERAL TASKS

## OF UNIDO EXPERTS

## DURING FACT FINDING MISSION

- OBSERVATION OF OPERATION AND PROCESS

- STUDY OF AND INFORMATION ON THE OBSERVANCE OF METALLURGICAL PARAMETERS AND SPECIFICATIONS

- COLLECTION OF INFORMATION ON PREVENTIVE MAINTENANCE OF THE EQUIPMENT

- ELABORATION OF ACTUAL SITUATION, INSUFFICIENCIES, OBJECTIVES, RECOMMENDATIONS, METHOD OF IMPLEMENTATION AND EVALUATION OF THE REHAB PROGRAMME FOR EACH PLANT

- DISCUSSION OF METALLURGICAL PROBLEMS WITH PLANT MANAGER AND ENGINEERS

## REHABILITATION PROGRAMME WORK METHOD

ANALYSIS OF ACTUAL SITUATION

|

INSUFFICIENCIES

|

OBJECTIVES

|

RECOMMENDATIONS

|

IMPLEMENTATION

BY ROLMIL

BY UNIDO

|

EVALUATION OF RESULTS

## SIGNIFICANCE

## OF ROLMIL KENYA

- founded as a mere steel merchant organisation (private)

- 1980: establishment of an open one-line rolling mill
  1 pusher type reheating furnace, 7 stands
  capacity: 47 t/day (one shift, 12 hrs)

- 1985: erection of one 6.5 ton/EAF
  EAF: 33 t/day (5.5 heats of 6 tons of ingots each, 24 hours production)
  tap-to-tap time: 220 - 260 min (100 % scrap charging)

- Ingots: app. 46 kg/piece, 9500 MT/year
  (equivalent to app. 7000 t of rolled products)

- Production programme: rounds 8 - 32 mm
  squares
  flats
  angles, T and Z-sections

  Grade: St 37 and 42

- 110 employees (70 Rolling Mill, 40 EAF)

- Production at start of project: approx. 9000 t (liqu. steel)
  corresp. to approx. 6800 t finished product

## 1.2 Presentation of Project Highlits

(Findings/Recommendations/Objectives/Results)

# Improvement potentials

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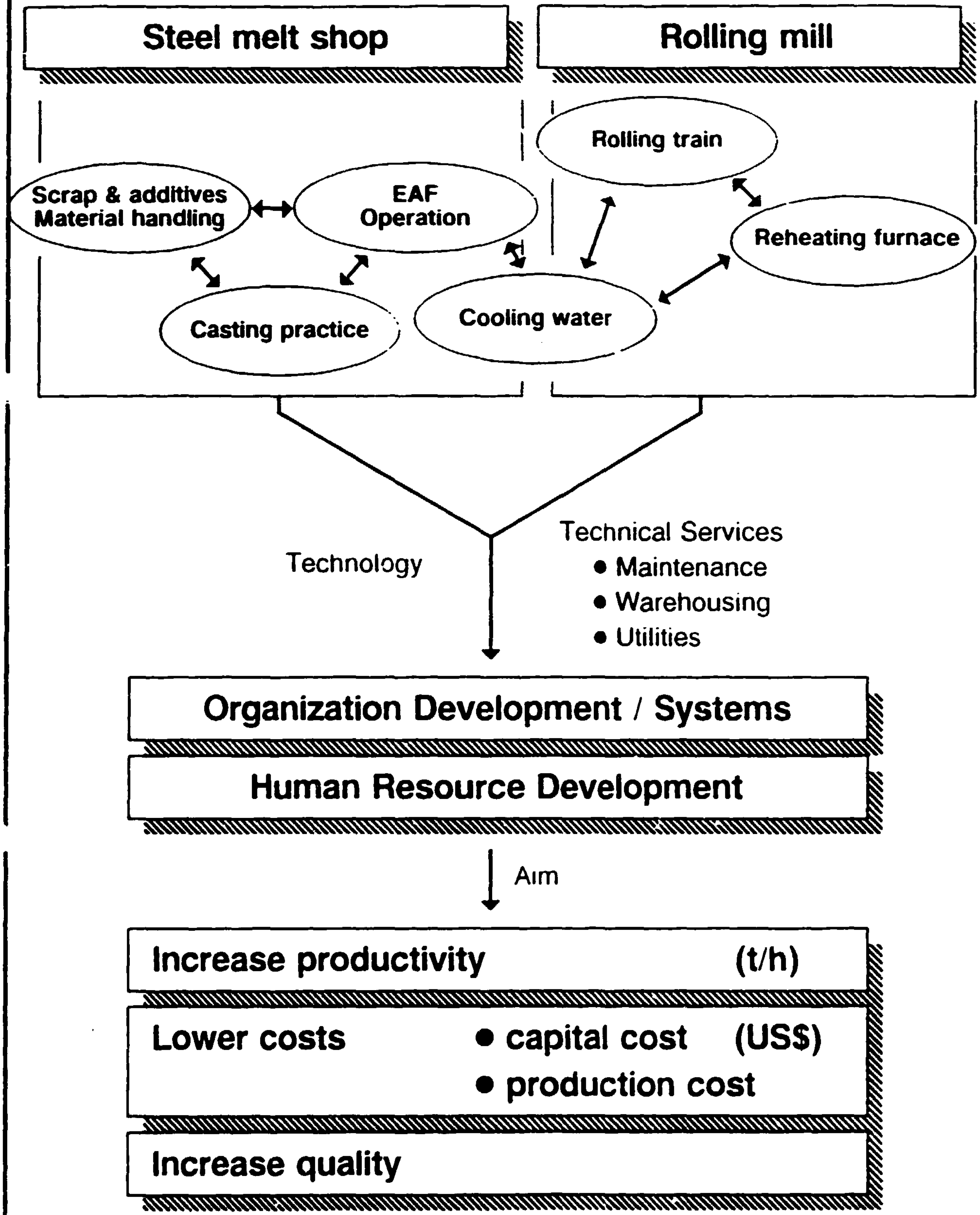
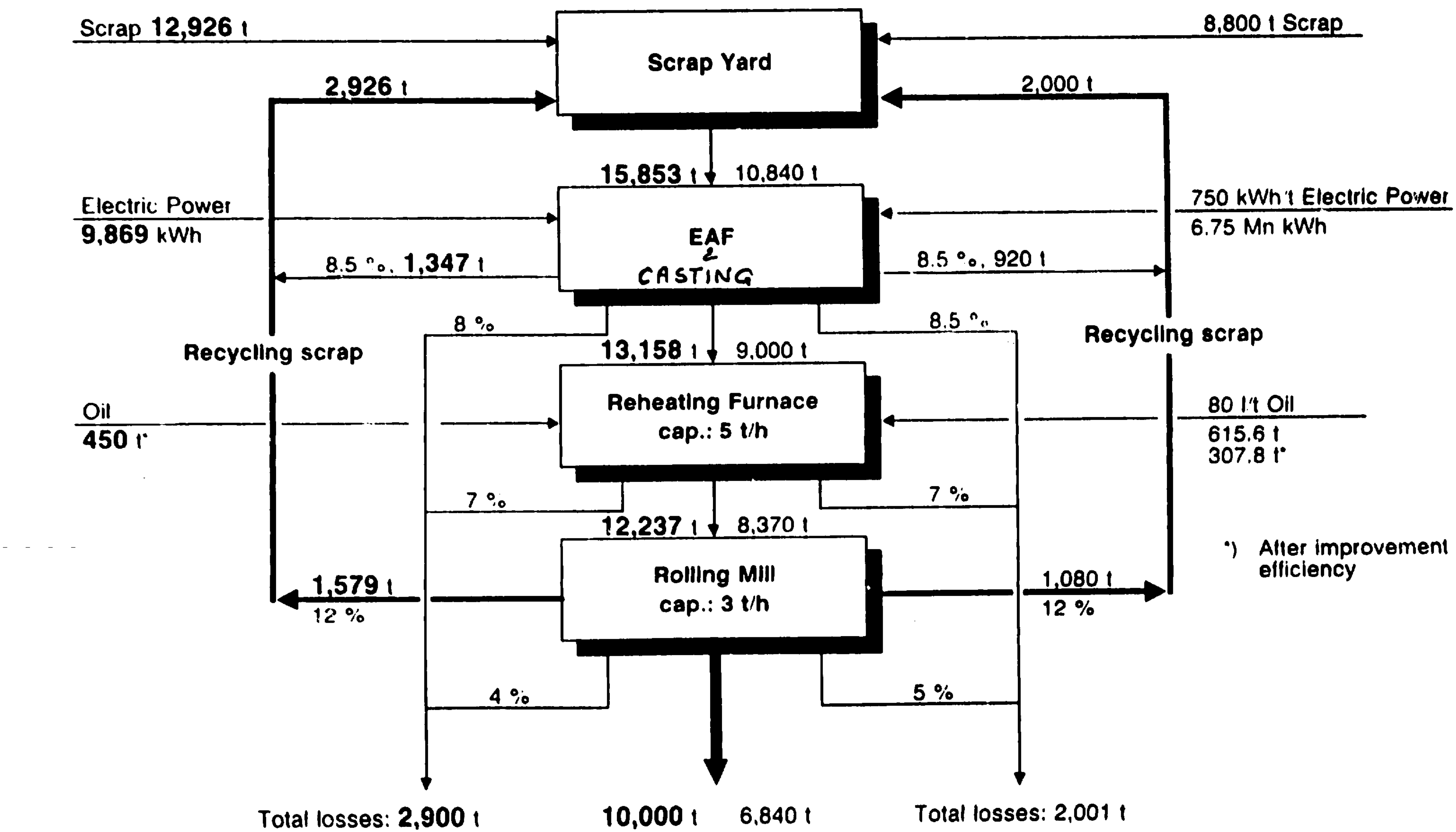


# Rolling Mill: Material/Energy-Balance:
(t/year)

**Planned Production:**
(after implementation of recommendation)

Actual Production:




*) After improvement efficiency

## SCRAP YARD AND PREPARATION, HANDLING OF BUCKETS

**Insufficiencies / Actual Situation:**

- no uniform scrap mix/bucket obtained
- scrap stock insufficient
- automobile scrap contains oil
- bulky light scrap and scrap length exceeding 1.3 m
- 6 scrap yard workers fill buckets manually
- no scrap blending, no weighing

**Objectives/Recommendations:**

- build up a stock for at least one month production
- reorganisation of scrap handling:
    - scrap classification by type of scrap
    - compress light scrap
    - cut long scrap
- procurement of:
    - one transportable bundle press
    - one transportable alligator shear
- charge EAF with 3 buckets/heat
- establish uniform scrap mix/bucket

**Implementation (as of Dec. 1990):**

- Assistance in procurement of cutting shear and bailing press
- Increase of man power for scrap preparation
- Quality of scrap improved very little
- Quantity of scrap on stock increased significantly

# STEEL MELT SHOP

## Fact Finding Situation

Useful life of wall : 140 heats
roof : 150 heats
bottom : 500 heats

Melting process: average heat output 88 - 90 %
6.8 t scrap charged for 6 t liquid steel
(7 buckets/heat)
tap-to-tap time: 15 min repair time
130 min melting time
75 min refining time
temperature: approx. 1600° C (visual check)
high power consumption (800 KWh/t liquid steel)

Casting pit: cast into 72 inverted conical tarred moulds
(bottom casting)
ingot dimension: 2.5" x 3.5" x 48"
casting time: approx. 8'

Ladle: six 6.5 t bottom-tap ladles, heated up to 900° C;
durability: approx. 75 charges/ladle

Additions and Alloys:

Limestone: 300 kg/heat, unit size too big, no burnt lime used
Fluor Spar: 91 % $CaF_2$, max. 5 % $SiO_2$, 0.01 % S
Carburizing Agent: crushed brown coal or charcoal (C efficiency extremely low)
Alloys: FeMn standard (6 % C), FeSi 75 %

# STEEL MELT SHOP

**Objectives:** Increase of production by:
- reduction of tap-to-tap time
- reduction of specific energy consumption
- reduction of specific refractory consumption
- improvement of heat yield

**Recommendations:**

- optimization of furnace operation (reduction of melting time and refining time, specific energy and refractory consumption) by
  - use of oxygen
  - introduction of foamy slag process
- procurement of
  - temperature measuring equipment
  - "spectrometer" for lab
  - analysis equipment (min. C and S)
- increase of ingot weight
- technical assistance and training programme for engineers and operating crew with emphasis on:
  - oxidation
  - foamy slag process
  - dephosphorization
  - deoxidation
  - desulphurization
  - temperature control
  - slag control

# STEEL MELT SHOP

**Implementation:**
- installation of temperature measurement equipment
- start with use of oxygen
- erection of a new laboratory
- purchase of a carbon-sulphur-analyser, start operation, training of personnel
- organisation of a training programme for engineers and operating crew for EAF practice
- increase of ingot weight

**Result:**
- operation of temperature measuring equipment (immersion thermocouple) and carbon-sulphur-analyser
- reduction of off-heats
- investigations were carried out concerning further reduction of tap-to-tap time by installment of oxygen blowing facility (reduction 10 -20 minutes, depending on scrap quality)
- general improvement in the melting process by thorough training of furnace operators
- improvement of casting yield due to increase of ingot weight

# REHEATING FURNACE

**Actual Situation / Insufficiencies:**

- capacity 5 t ingots/h
- started up in 1979
- installation in very poor condition
- no monitoring equipment
- high fuel oil consumption (approx. 100 l/t finished product)

**Recommendations:**

- elimination of furnace defects
- recuperator should be installed immediately
- procurement of
  - oil flowmeter
  - air flowmeter
  - $O_2$ measuring equipment
  - gas-temperature meter
  - air-temperature meter
  - furnace pressure measuring equipment
- care should be taken that all furnace doors are completely closed

# REHEATING FURNACE

**Objectives:**

- installation and insulation of recuperator and hot-air pipe
- installation of oil flowmeter, O2 measuring equipment and furnace temperature equipment to control combustion
- long-term investigation for a new furnace

**Results:**

- recuperator was installed which resulted in an effective fuel savings of approx. 19 % (current consumption 65 l/ t)
- additional measuring devices were recommended to increase savings by at least another 10 %

# ROLLING MILL

## Actual Situation / Insufficiencies:

- 7 stands, started up in 1979
- overall state and output satisfactory
- output: 850 t finished products in 261 production hours (3.25 t/h)
- drive gear suffered damage, not yet replaced

## Recommendations:

- installation of the ordered gear as soon as possible
- procurement of tensile strength testing
- procurement of optical pyrometer

# ROLLING MILL

**Objectives:** - check of the rolling-mill drive gear

- inspection of load suspension devices

**Results:** - drive gear installed (but running characteristics still not satisfactory - claim against manufacturer necessary)

- heat losses still high due to unfavourable discharging procedure

- sufficient capacity reserves available

- due to the installation of the recuperator, the combustion-oil consumption has been decreased to 65 l/t

# MAINTENANCE

**Actual Situation / Insufficiencies:**

- no maintenance workshop
- stock of manual tools and machine tools insufficient
- current maintenance problems
  problems with oil-consumption of reheating furnace
  problems with travel drive of the meltshop 10/4 t crane
- not all safety regulations are observed

**Recommendations:**

- procurement of original spares
- establishsment of a systematic preventive maintenance service:
  - organization as third technical division with fixed tasks
  - small central workshop
  - employment of an experienced European maintenance technician for training

**Objectives:**
- regular maintenance of cranes
- purchase of new original spare parts
- erection and furnishing of central workshop (support in specification and purchase of equipment and tools)

**Implementation:**
- central workshop with several machines and tools installed

- personnel instructed in utilisation of equipment and tools

**Results:**
Due to improved maintenance a significant increase in production and in the quality standard has already been achieved; full effectiveness is expected in the long run.

# 2. Technological Aspects of Improvement Programme at EAF-Plants

## 2.1 Review of EAF Technology Development

For most of the PTA-countries the electric arc furnace is the best equipment to produce steel economically, for the following reasons.

- good-high standard equipment is also available for smaller prod. capacities (5,000 - 100,000 tpy)
- the plants can use locally available scrap
- electrical energy, generated mostly from local sources, is available
- the foreign currency share in the production cost is low

Worldwide almost 25 % of the produced steel is EAF-steel and great efforts have been made to improve EAF-technology in the past 25 years. Development aspects briefly discussed are split into four groups (see Fig. 2/1).

The results of the efforts are considerable:

- reduction of tap-to-tap time from 180 min to 55 min
- reduction of electrical power consumption from 630 KWh to 330 KWH
- reduction of electrical consumption from 6.5 kg/t to 3 kg/t

(see Fig. 2/2 and 2/3)

With these improvements, the EAF process became a competitive method to also produce normal commercial steel qualities. Although the new technologies were developed primarily for the large EAF units , the smaller units will also profit from these developments by suitable adaptation of new technologies.

### 2.1.1 Scrap

The preparation of scrap before charging is very important. It is the first precondition for the increase of the productivity of the electric arc furnace. This preparation can be done in a physical (mechanical) or in a chemical way.

# Review of Technological Development Aspects for EAF Practices

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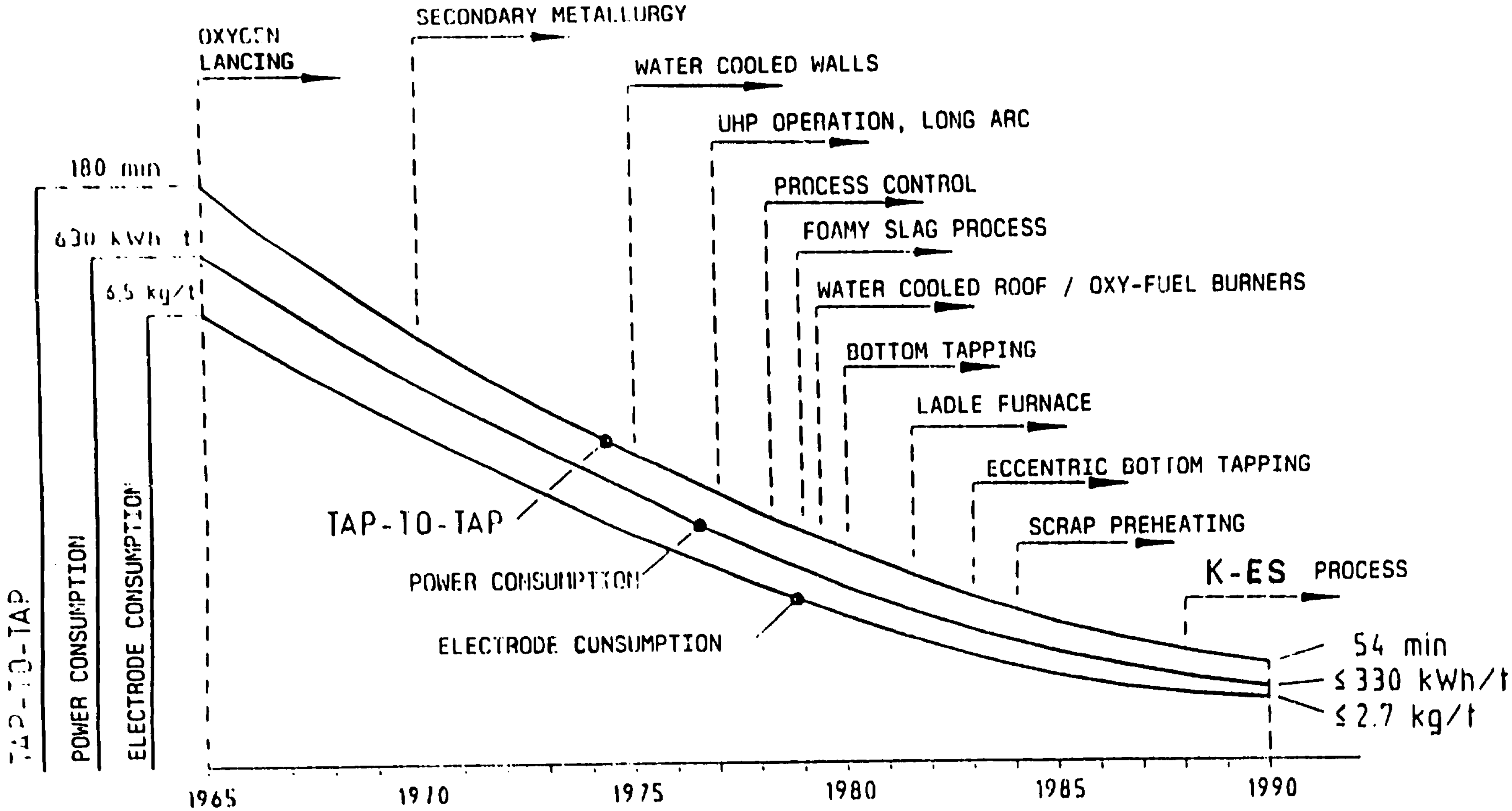
**Fig. 2.1**

| | |
|---|---|
| Scrap handling<br>I | Scrap classification<br>Scrap preparation |
| Energy input<br>II | UHP-transformers<br>Oxy-fuel burners<br>Use of oxygen for scrap melting and decarburization |
| Design measures<br>III | Water cooled furnace panels<br>Water cooled electrode sections<br>Bottom tapping |
| Process adaption<br>IV | Foamy slag practice<br>Ladle refining |

# Fig. 2.2 Development of EAF technology



# Development of tap to tap times of electric arc furnaces

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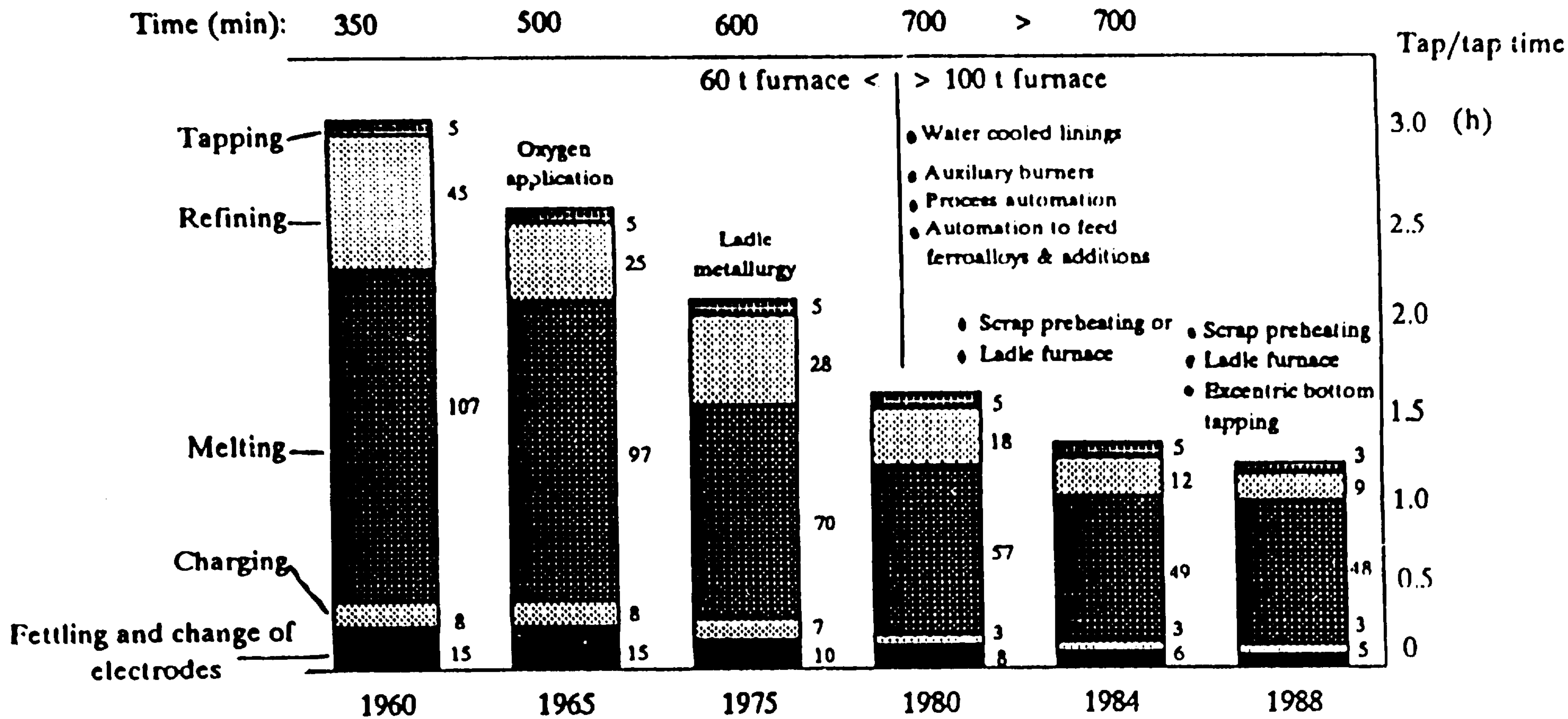
**Fig. 2.3**



**Physical (mechanical) preparation**

Mechanical preparation is done by: flame cutter, scrap cutter and presses. The purpose of this preparation is to get a scrap which can be charged at most into 2 buckets per heat.

The cost of charging an additional bucket is the cost of approx. 5 minutes of furnace operating time. Including the related energy and electrodes, it is often stated that the cost of furnace time loss is about US$ 1/min/t.

The trend in unalloyed steel producing is to have nearly the same conditions not only in scrap charging but also in chemical composition at the melt down point in the EAF.

Therefore it is very important to classify the scrap at the scrap yard into different scrap classes.

**Chemical preparation**

In order to guarantee the specified conditions (uniform chemical analysis) it is necessary to classify the scrap and to take samples if there are doubts about the composition.

In summary, the scrap required for effective and smooth work in the EAF should have uniform physical and chemical composition with a density of approximately 800 kg/m3 so that it can be charged with 2 buckets per heat.

For more details see lecture on scrap preparation.

## 2.1.2 UHP-Transformers

Transformer rating per ton of furnace capacity is steadily increasing

| | | |
|---|---|---|
| 500 KVA/t | 650 KVA/t | 850 KVA/t |
| 1975 | 1980 | 1990 |

Individual adjustment of voltage for each phase allows the control of "heat spots" and maintenance of max. power input.

Cost factors are clear and can be accurately indentified.
Attention must be given to control device for electrodes, flickers and process

For modern EAF: Tap to tap time is betw. 60 - 90 minutes for standard carbon steel

**Oxy-fuel burner**

Oxy-fuel burners are now almost standard equipment on arc furnaces. The main reason for installing burners on larger modern furnaces is to heat the cold spots and promote uniform melting, thus increasing output speed. However, depending on local energy sources, useful energy cost savings can be achieved.

Capital costs: not remarkable

Reduction of tap to tap time is in the range of 10 min.

**Attention**: handling of increased off gas volume & temperature

## 2.1.3 Use of Oxygen

EAF operators use oxygen during the melt down period as well as in the oxidizing period to speed up the reduction of the carbon content of the bath (Flow rates up to 1.5 NM3/t, min)

The use of oxygen increases the efficiency of the arc furnace in reducing the "power on" and tap to tap time.

Oxygen is injected by manual lances or by lance manipulators.

**The advantages of lance manipulators are:**

- improved operation, safety and working conditions
- reduction in time, electricity and electrode consumption
- closer control of foaming slag generation and decarburisation due to the adjustable lance angle
- possibility of lime injection into the liquid bath.

The use of oxygen allows unalloyed steel producers to operate the EAF with only one slag/heat (depends on allowable sulfur and phosphorous contents)

**Attention**:

- handling of additional "off gas" volume required (modification to "off gas" installations)
- Work with oxygen requires special measuring & control devices and training

## 2.1.4 Water Cooling

The installation of water cooling on the EAF has been an important aspect of high power operation. Water cooling has been applied to side wall, roof and more recently to the furnace electrodes. (see Fig. 2/4 and 2/5)

**Water-cooled side wall panels**

The reliability of panel life of water cooled side walls has increased significantly (10,000 heats). The typical coverage is 70 to 75% and the thermal loss from the furnace is 5 to 10% of the total energy input.

**Water-cooled roofs**

A low pressure system has been developed for spray cooling the roof in the event of system failure. The water entering the furnace is much less for low pressure cooling with consequent safety implications.

**Water-cooled electrodes**

A simple method has been developed in spraying water on to the electrode via a spray ring mounted under each clamp. Graphite savings in the order of 5 to 10% are claimed. The major benefits have been prolonged roof lives for delta refactories.

## 2.1.5 Electrodes

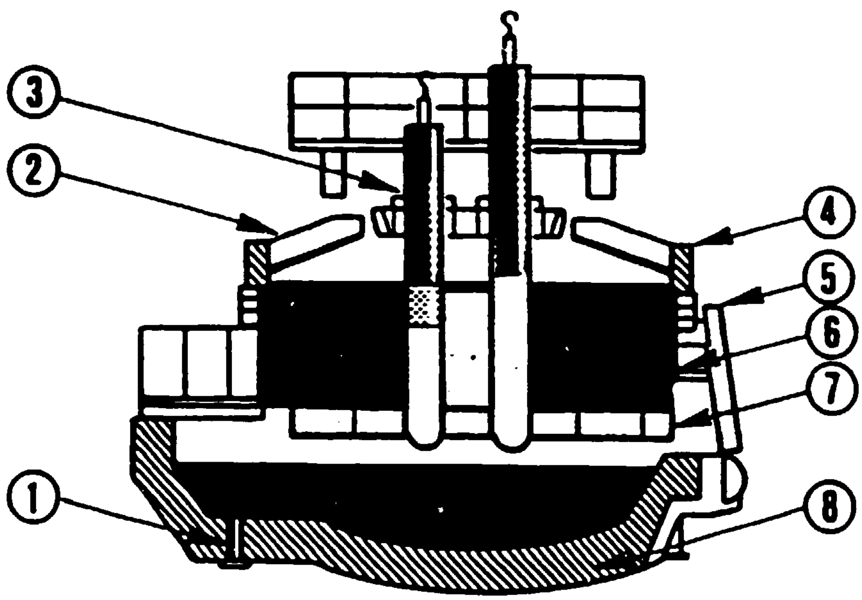
Reduction of electrode consumption in recent years has been brought about by improved electrode characteristics and by plant/process innovations. (see Fig. 2/2)

Foamy slag practice and water cooled panels allow lower currents. Ultra high power operation, oxy-fuel burners, and injection of large quantities of oxygen are reducing the tap to tap time and therefore the specific electrode consumption.

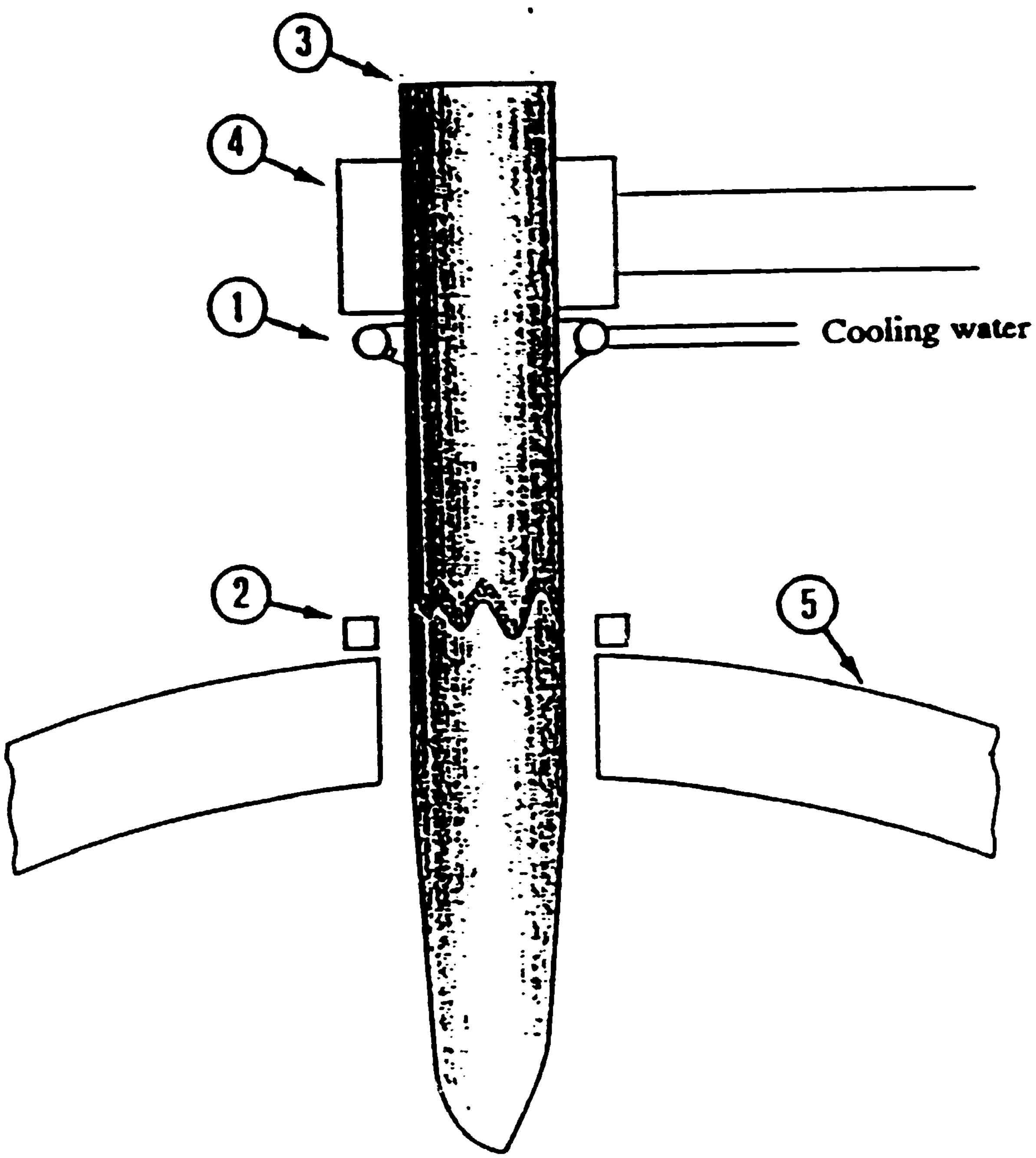
The reduction of buckets per heat (at most 2 per heat) reduces the side oxidation of the electrodes and the electrode consumption.

A water-cooled electrode system is a simple and effective way of reducing electrode consumption. This system is also known as the electrode direct-cooling system

# Fig. 2.4 The Internal Profile of an EAF




| | | | |
|---|---|---|---|
| 1 | BOTTOM TAPHOLE | 5 | SHELL |
| 2 | ROOF PANELS | 6 | STEEL WC PANELS |
| 3 | ELECTRODE SEALING RING | 7 | COPPER WC PANELS |
| 4 | WATER COOLED ROOF | 8 | BOTTOM |




1 = Cooling water nozzles
3 = Electrode
5 = Furnace roof refractory

2 = Seal ring
4 = Electrode holder

**Fig. 2.5**

## 2.1.6 Bottom Tapping

The tap-hole is located in the bottom of the furnace; tapping is done similar to ladle practice with slide gates to open and close the tap hole.

Approximately 50% of the world's arc furnaces are of the bottom taphole design, the two main types being eccentric bottom tapping (EBT) and offset bottom tapping (OBT). (see Fig. 2/6)

**Eccentric bottom tapping (EBT)**

The bottom half of the furnace is fitted with an eccentrically located taphole by widening the tapping area and removing the conventional spout:

- Slag free tapping: The furnace tilting angle of approx. 15° allows for rapid back tilting after tapping to retain slag or liquid steel in the furnace,i.e. "Hot heel practice".

- Compact tapping system results in less heat loss and hence lower tap temperatures (30°C), less hydrogen and nitrogen pick up, increased steel cleanness.

- Shorter tap times, e.g. 150 tonnes in 2 minutes

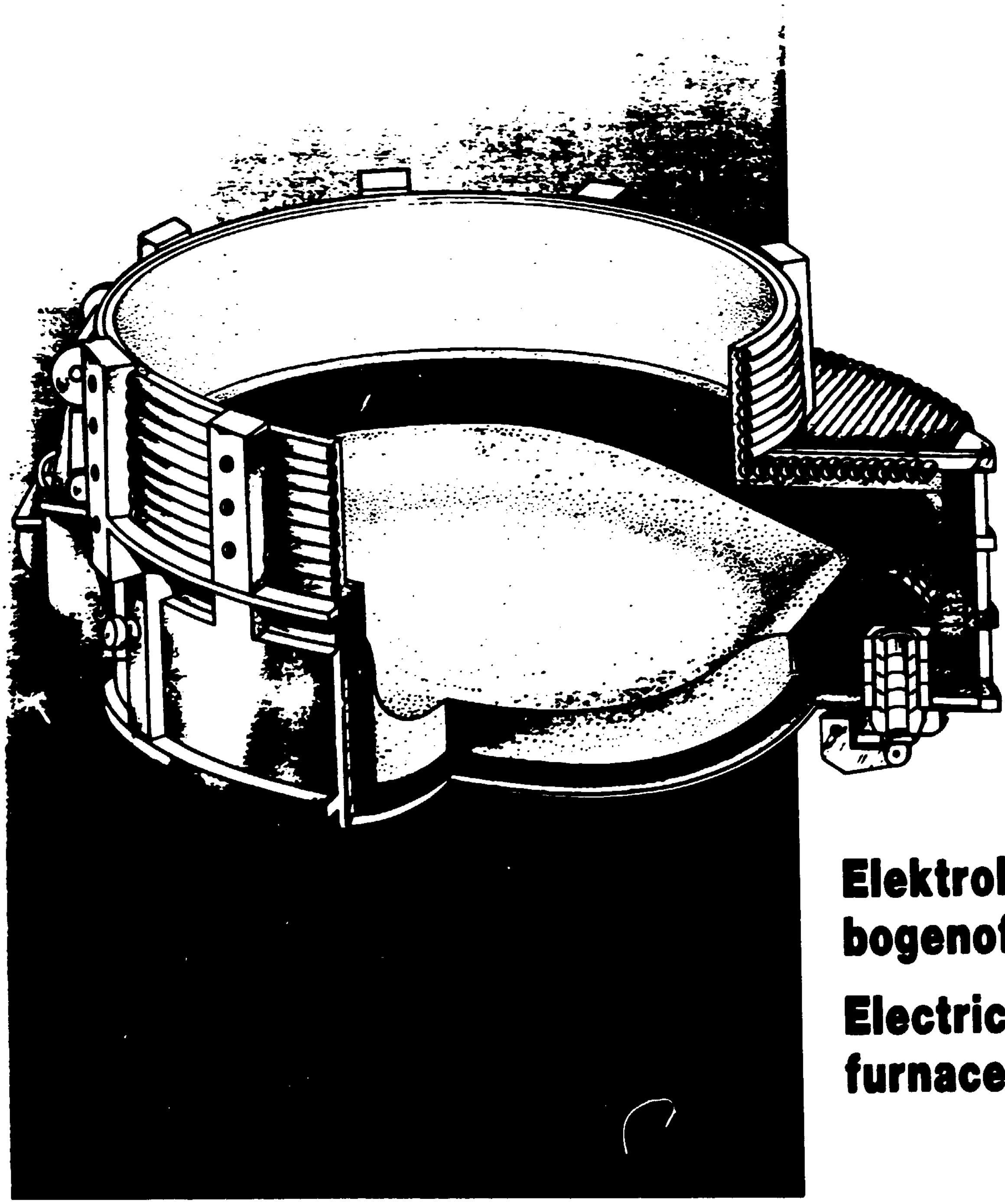
- Quicker furnace turn-round due to easy maintenance of taphole mechanism through the balcony to panel

- Refactory savings due to increasing the side wall panel area to 87 - 90%.

**Offset bottom tapping (OBT)**

OBT is similar to EBT except the bottom shell taphole area modifications extend to the upper shell and roof to remove the balcony section.

Fig. 2.6



**Elektrolicht-bogenofen**

**Electric arc furnace**

The advantages of OBT are the same as for EBT and a similar taphole closure mechanism can be used.

Considerations about refractority materials and linenes used in modern EAF practice is given in Annex 1.

### 2.1.7 Foamy Slag Process

Current practice in electric steelmaking demands that the arcs be covered with slag for as long as possible in order to increase efficiency in transfer of electric energy (see Fig. 2/7) and to minimise heat losses and refractory wear.
Additionally there is a remarkable reduction in noise as the three arcs are drowned by a rising, foaming slag.

**Gas bubbles**, which are necessary for the formation of foamy slag, have two points of origin:

1) In the bath: through CO-gas as a reaction product of oxygen and carbon content of the melting charge, assuming that the carbon content of the bath is high enough at the beginning

2) In the slag: through reaction of carbon with the ($FeO_n$) of the slag

Note that 80% of gases needed for a foamy slag have their point of origin in the slag and only 20% in the bath, which means that the reduction of slag's ($FeO_n$)-content is the most important supplier of the gases.

**Viscosity** and **Temperature** of the slag have great influence on formation of foamy slag

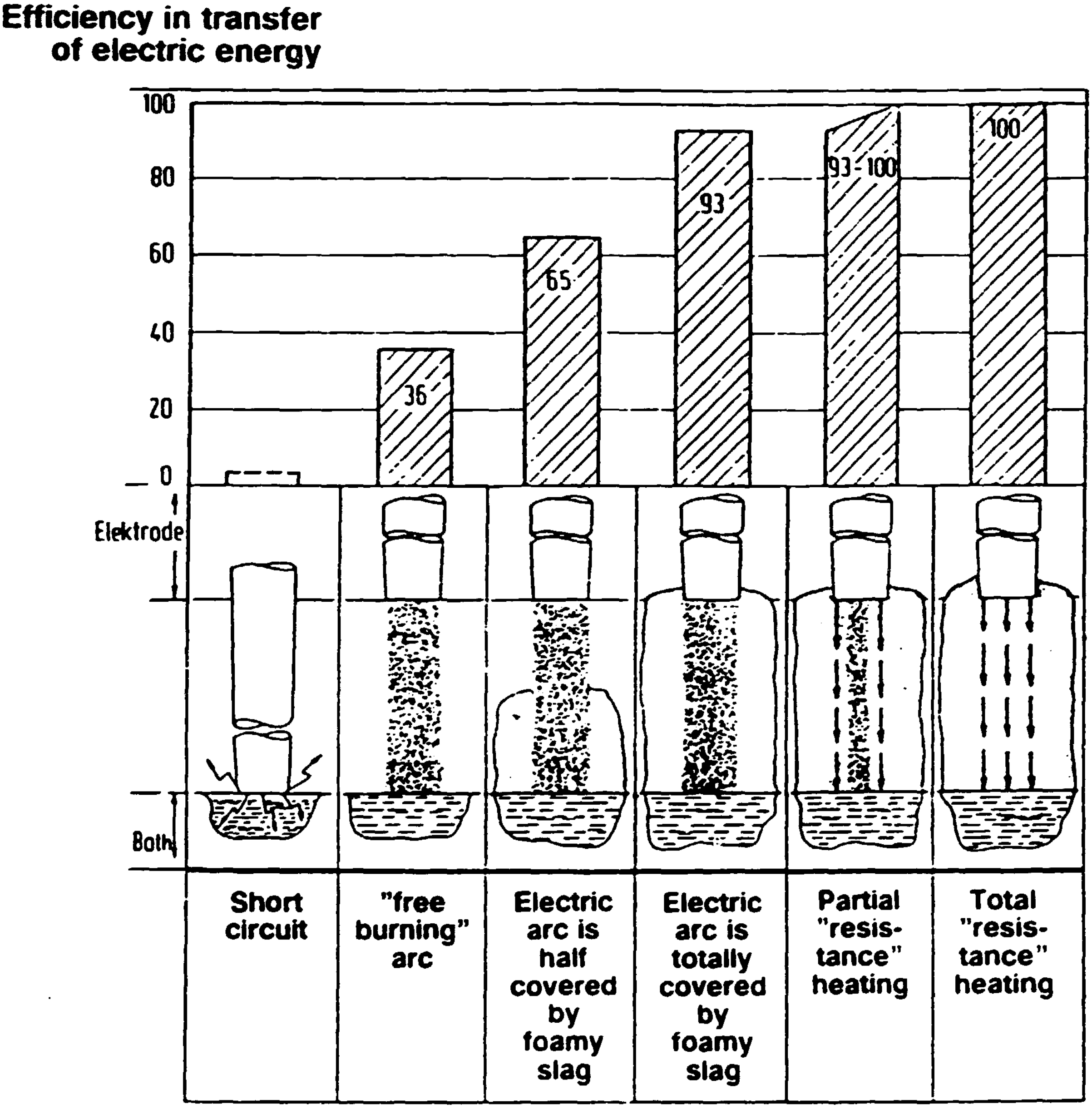
($FeO_n$), (MnO), (CaO), and (MgO) effect a liquefaction, ($SiO_2$) and ($Al_2O_3$) increase the viscosity of the slag.

The hotter the slag the worse are the conditions for a foamy slag.

A high **surface tension** slows the rise of the gas bubbles in the slag and creates better conditions for foamy slag.

# Influence of foamy slag on efficiency in transfer of electrical energy from electrode to melt

## Fig. 2.7



Surface tension is increased by (CaO), ($Al_2O_3$), (MgO) and (FeO) and decreased by ($SiO_2$), ($TiO_2$), ($P_2O_5$), ($NaO_2$) and (S).

**Interfacial tension** is also responsible for the passing of gas bubbles from the bath into the slag.

(C), (O), (S), (N), and ($SiO_2$) decrease the interfacial tension, while (CaO) increases it.

**Ferrous oxide activity** and slag **basicity** are also important factors for a foamy slag (see Fig. 2/8)

The lower the ferrous oxide activity are the better the conditions are for foamy slag formation.

45 to 50 kg of burnt lime per ton of steel are required for a foamy slag process (basicity between 1.5 and 2.5)

The foamy slag process also reduces by approximately 10-30 kWh/t the power consumption needed for overheating the bath (normally approximately 120 kWh/t).

### 2.1.8 Out of Furnace Refining

To meet the specified chemical composition, producers of unalloyed steels usually put the additives such as carbon, FeSi and FeMn into the ladle during tapping.

Customer demand for high quality steel has become increasingly severe. This demand has prompted development of an out-of-furnace refinement method. Due to the equipment cost savings and simplicity of operation, the ladle furnace method (Fig. 2/9), which can compensate for a drop in temperature using arc heating equipment, has become popular as ladle refining method.

In recent years ladle furnace evolution has been quite remarkable. First in terms of purpose, from improvement of steel metallurgical quality to increased shop productivity, secondly in terms of fields of application, from special steel EAF shops to BOF shops and now minimills, finally in terms of technological evolution.

The trend is towards simpler designs that achieve better control of electrical parameters, heat radiation, stirring facilities, air infiltration over the ladle and that also leads to easier operation.

# Infuence of $Fe_xO_y$ and basicity of slag on foam characteristic

## Fig. 2.8

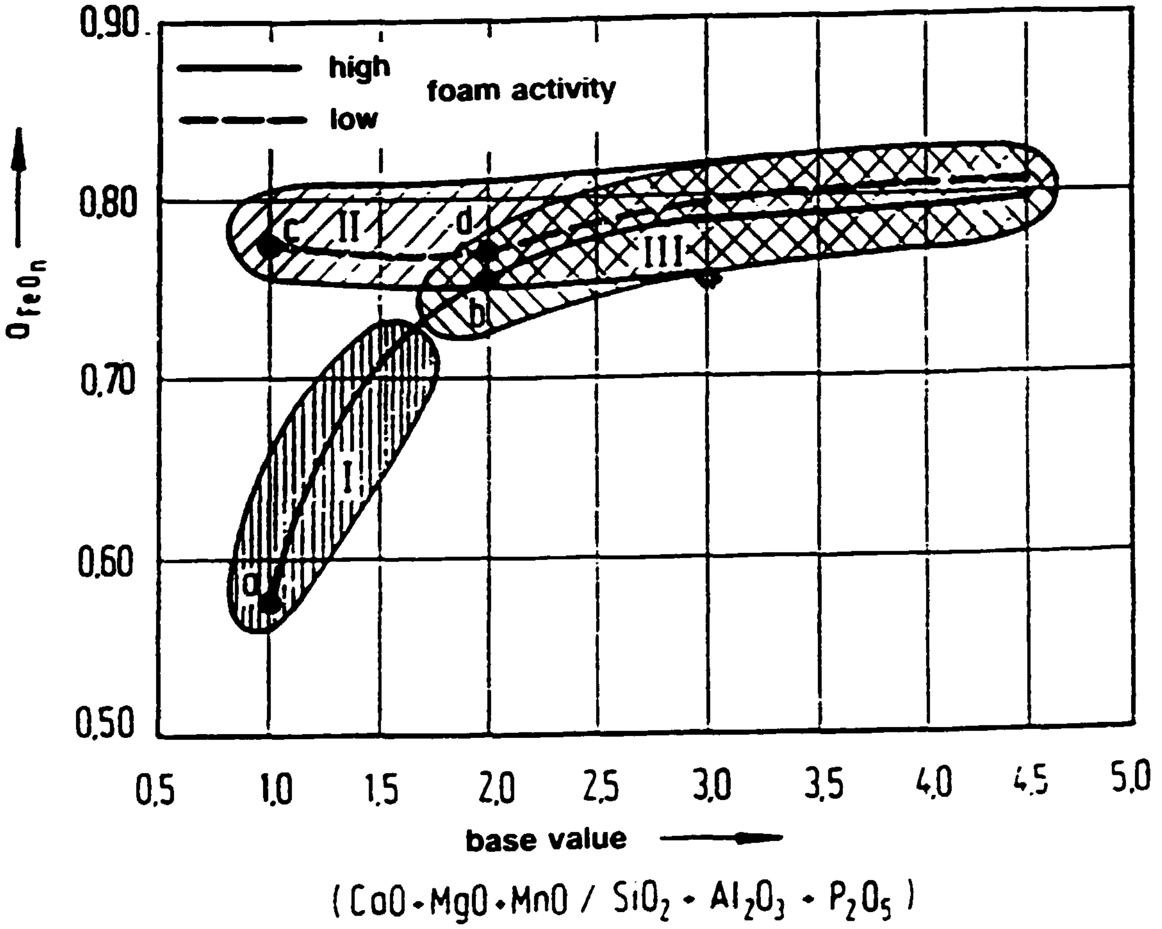
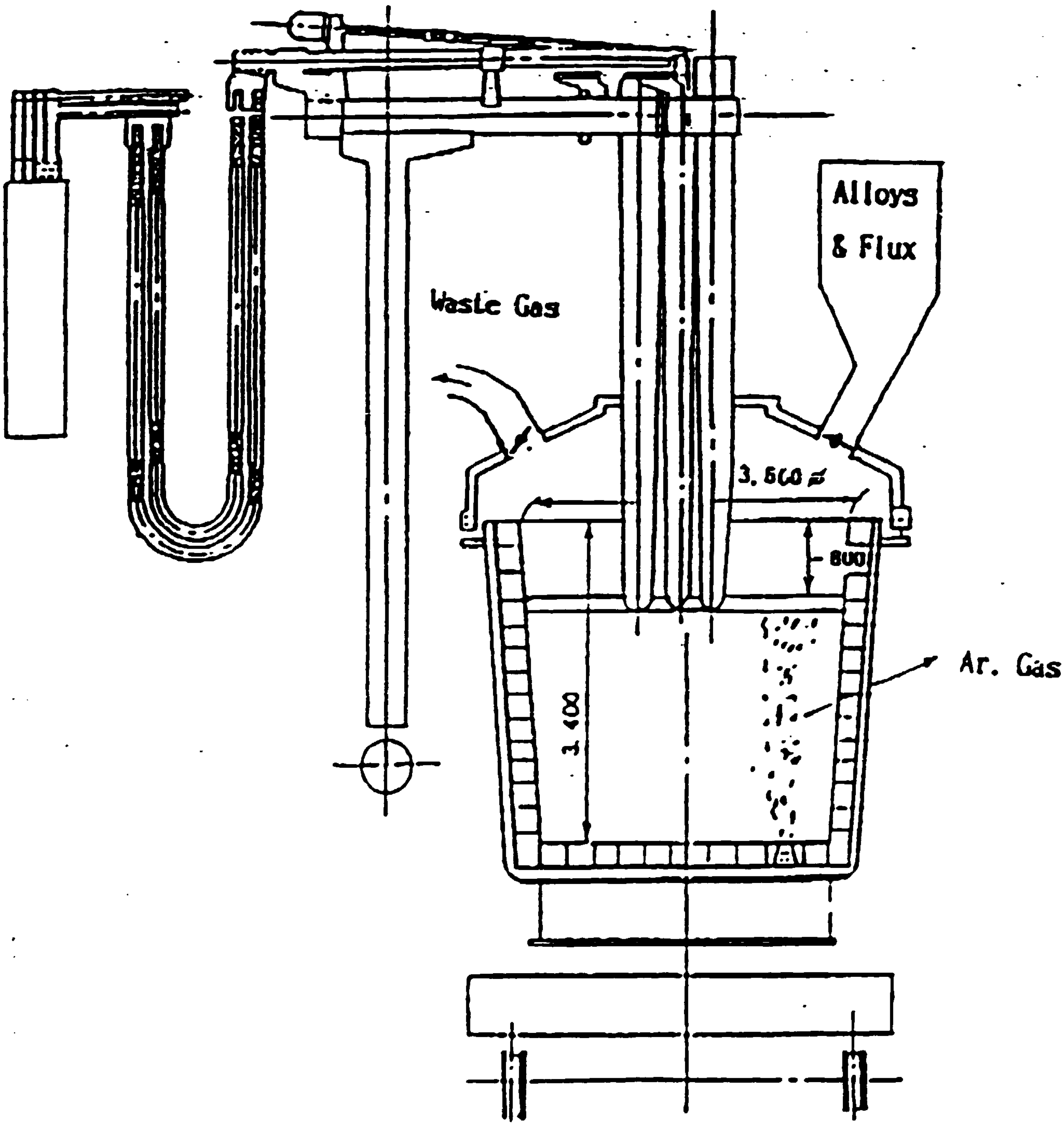


Fig. 2.9



The introduction of LF clearly helps to increase production, to lower the tapping temperature and shorten or omit the reducing period.

Ladle furnace unit consumption of electrical power varies from 20 to 75 kWh/t and the treatment time varies from 15 to 60 minutes per heat.

## 2.1.9 Final Remarks

These technical developments are not necessarily applicable to all furnaces, their relevance depending on the raw materials used and the quality of steel produced. It is a matter of individual assessment of each steelmaker to establish which combination of these techniques will give optimum performance. However, using these developments and so achieving increased production rates combined with reduced energy consumption and reduced refractory and electrode consumption, makes it possible for the electric arc furnace (under certain conditions) to achieve lowest operating costs.

## 2.1.10 Putting Theory into Practice

An example of appropriately using "new technologies" discussed above is given in Fig. 2/10 for a 25 t EAF shop.

Note:
- tap-to-tap time 85 min
- use of oxygen and door burner
- foamy slag practice
- for more flexibility in quality and time (billet caster), a ladle furnace is also installed

It would be a big mistake to think that only technological aspects are responsible for such results. Most important are accompanying improvements in organisation and systems and a well-trained and motivated operating team.
Importance of the human resource development measures to obtain the set goals is generally underestimated.
An introduction to this very important area and further considerations are given in Annex 2.

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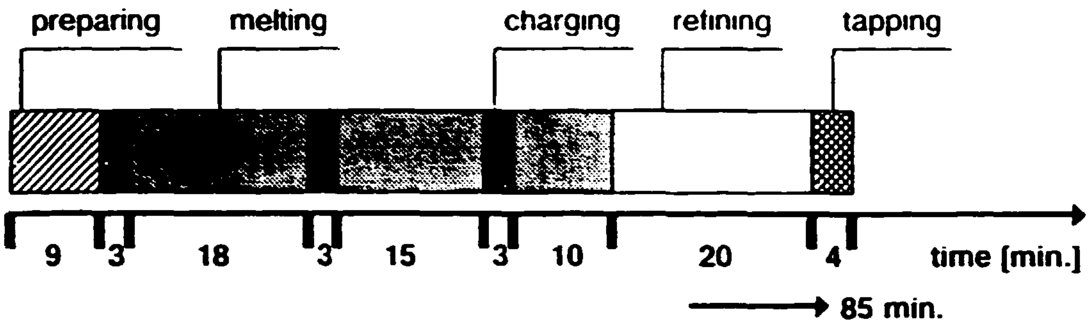
# Example of EAF Practice at a Modern Mini Steel Plant (25 to EAF, 16 MVA)

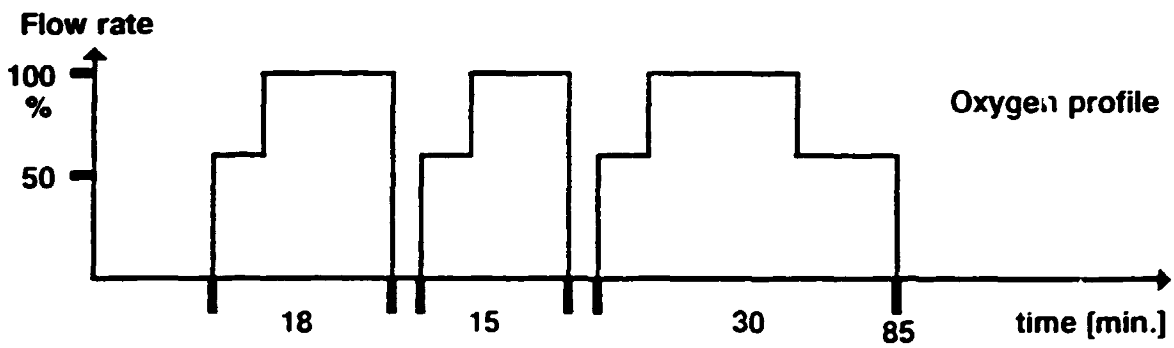
**Fig. 2.10**

## 1) Activity - time - diagram:

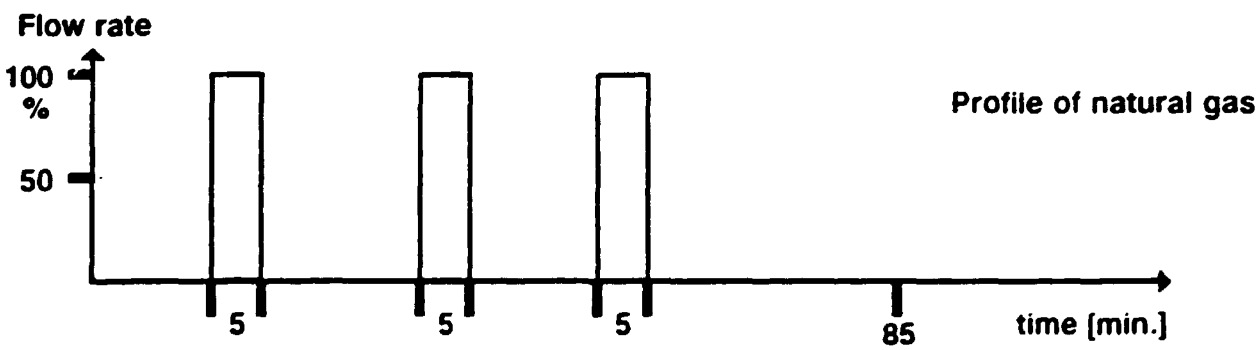



## 2) Energy input:

2.1 Electrical energy: "power on" 60 min., 450 kWh/t in average
2.2 Oxygen: average consumption 30 $Nm^3/t$ (including $O_2$ for burner)




2.3 Door burner: average consumption 4-5 $Nm^3/t$




2.4 Energy sources:

| | | | |
|---|---|---|---|
| 700 | kWh/t total | | |
| 450 | Elec.energy | 43 | Ladle furnace |
| 70 | Carbon (6-8 kg/t) | 20 | Elec. energy |
| 95 | Oxygen (25-30 $Nm^3/t$) | 63 | Sub total |
| 22 | Natural gas ($Nm^3/t$) | | |
| 637 | Sub total | | |

## 2.2 Scrap Preparation (Scrap Yard Equipment)

We have the impression that the salvage of scrap is an unsolved problem in your countries. This may not be a problem of the steelmaker. A private organisation or a government organisation should do this job. Scrap is a valuable, expensive raw material for steelmaking and therefore salvage should be better organised. The salvage of scrap is furthermore a classical example for recycling as far as Europe or the USA is concerned.
Importing scrap with foreign currency is not recommended because we are convinced that local scrap generated is sufficient for the local steel production.

In any case, the incoming scrap must be classified in the scrap yard of steelplant.
The scrap should be classified into

- sheet scrap, from sheet fabricating industry
- heavy scrap, engine gear box units
- long pieces, pipes, girders

Furthermore, it may be necessary to take samples from the incoming scrap if there are any doubts about the composition.
Generally the scrap should be stored before charging, sorted by the following classifications:

- high carbon steel,
- low carbon steel and
- different kinds of alloyed steels.

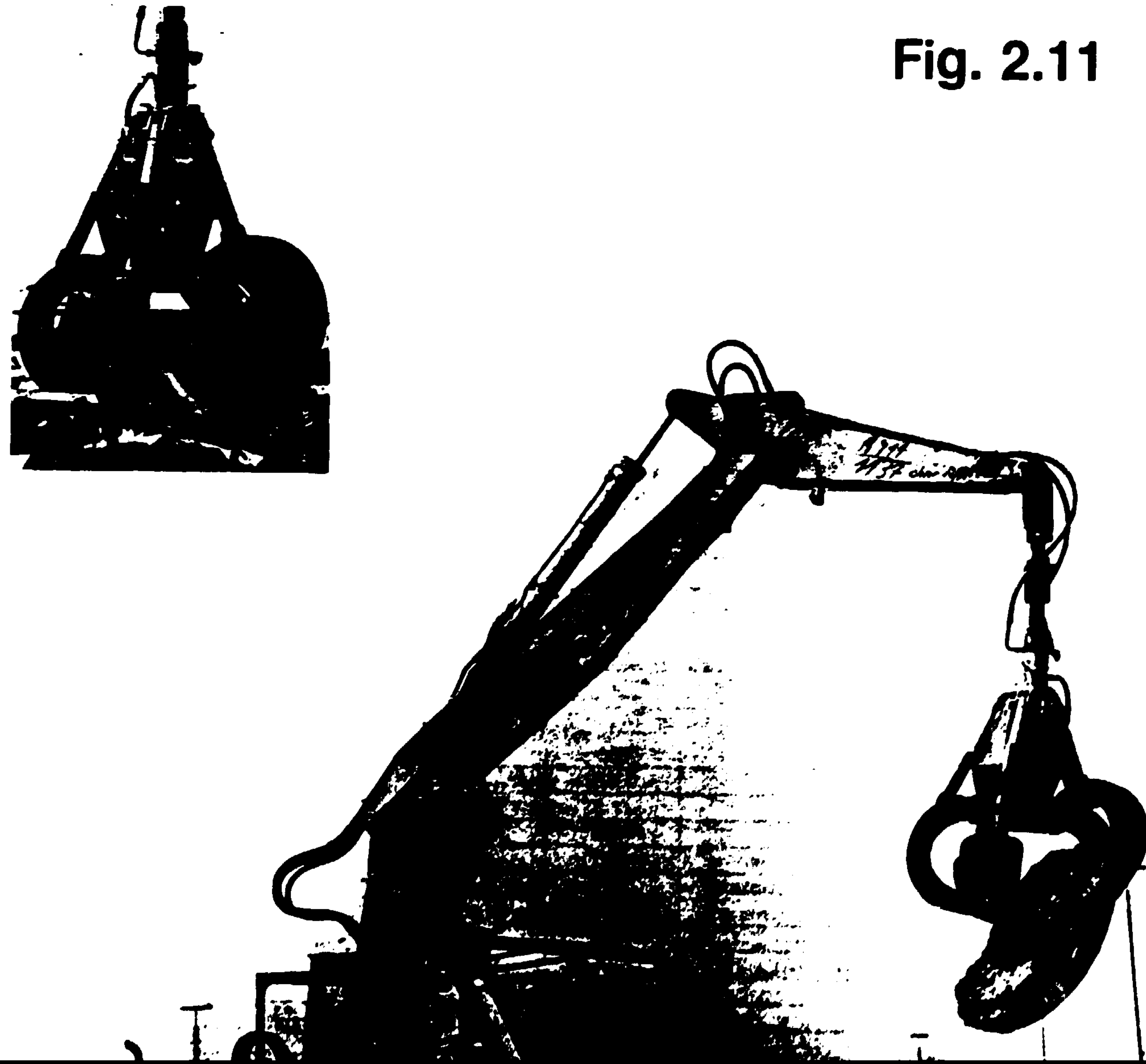
The classification and preparation of scrap before charging and the knowledge of chemical analysis, especially carbon content and other components (copper), are very important. Improvement of scrap yard practices is the first precondition for increasing productivity and quality of the final product.

For handling the scrap the following equipment should be available:

**Mobile crane:**

Figure 2/11 shows a crane driven by diesel engine with hydraulic drives for slewing, hoisting and lifting and mechanical drive for travel.
The crane can be equipped with a grapple or orange peel bucket or with a magnet.
The maximum capacity is 12 metric tons depending on the outreach. In this position the lifting capacity may be 6 tons. The maximum reach should be 10 m.
The volume of the hydraulic driven grapple is 0.6 m3, for long travel all 4 wheels are driven by mechanical gears.
The hydraulic circuit normally operates at 200 bar and is fed by axial pumps.
The working area is 360°.
Safety equipment, including turnover load limit, must be installed.
In front of and behind the crane is a trailer coupling.
This type of crane may be used for smaller scrap yards up to a steel production of 100,000 t/year.

Fig. 2.11



For bigger scrap yards, overhead-travelling cranes are used, usual with a capacity of 40 tonnes and equipped with magnets as showu in the next picture.

**Scrap shear:**

The long and heavy pieces must be cut before charging.
The mechanical preparation of scrap can be done by flame cutting or scrap shears.
Flame cutting is very expensive and should be done only on a case to case basis.

For small capacities hydraulic alligator-shears are used (see Fig. 2/12). The technical data for this type of shears follow:

**Shear Output:**

(Material up to 45 kg/mm2 resistance)

| | |
|---|---|
| Steel profiles | 240mm |
| | 220mm |
| | 100mm |
| Round Steel | 60mm |
| Square Steel | 55mm |
| Flat Sheet Steel up to | 30mm |

**Technical Data:**

| | |
|---|---|
| Length of Blade | 630mm |
| Shear Jaws Adjustable | 260mm |
| Shearing Count Adjustable | 20-30 cuto/min |
| Pressure | 45 t |

**Power Unit:**

| | |
|---|---|
| Diesel Engine | 17,5 kW |
| Electric Motor | 15 kW |
| Connected Load | 50 amps |

Through a comprehensive operator control system, comfortable efficiency and safety are attained. Mobile or stationary machines are available according to local conditions, with electric motor or diesel engine.

For bigger capacities shears are used with shearing power of more than 1000 t opening passage in the shear frame of 1000 mm x 800 mm, shearing capacity up to 5 t per hour, and power consumption 250 kW.
These shears are used in big scrap yards.

# Fig. 2.12 Alligator Shear 45 t

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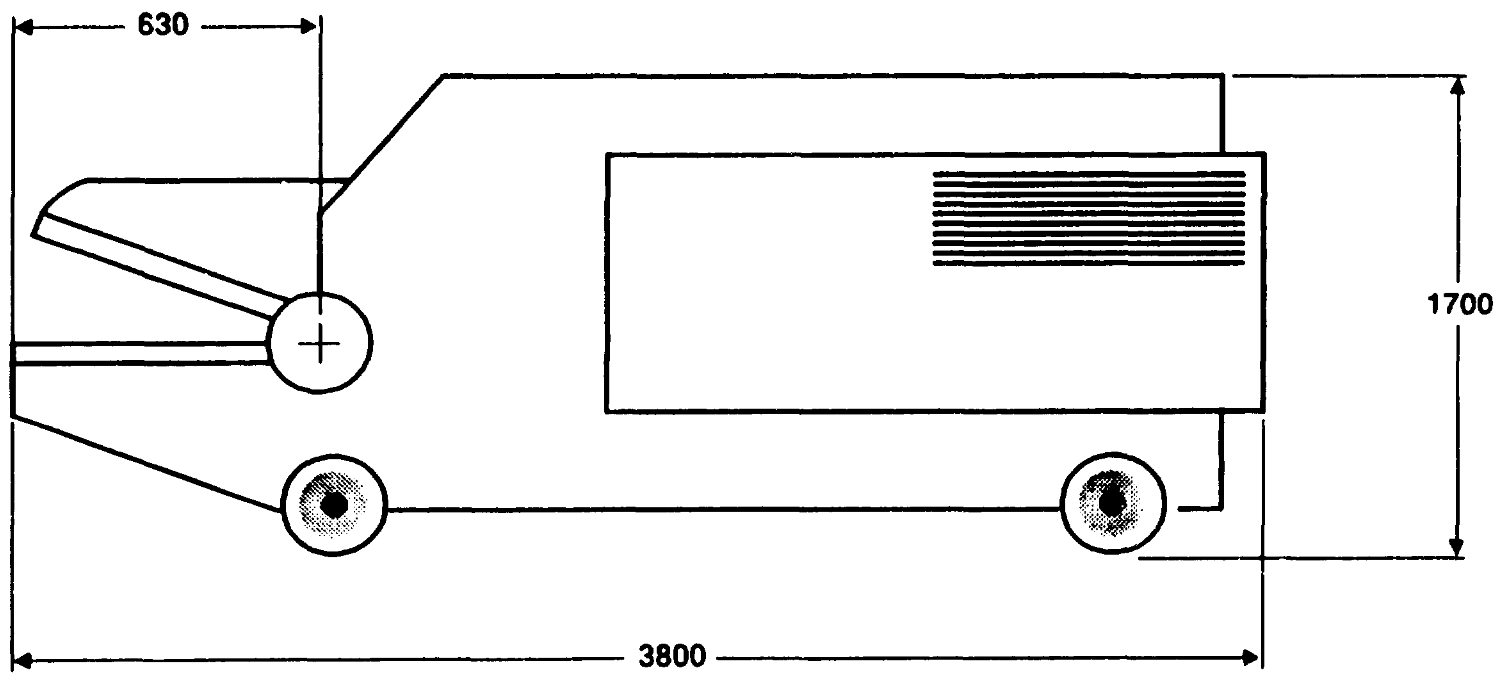


All measures in mm

**Baling press:**

For effective and smooth work in the electric arc furnace the scrap should have a density of approximately 800 kg per m3.

This can be obtained by means of a baling press, which may be the most important equipment in a functional scrap yard.

A modern three-compression scrap baling press is shown in Fig. 2/13. These presses with a side eject bale discharge are designed for the high speed baling of ferrous industrial sheets, factory clips and skeletons, non-ferrous sheet metals, shapes and wire.

The presses are equipped with adjustable shear knives on the front edge of the first compression ram which cut overhanging materials off.

The presses can be equipped with weighing hoppers if bales of equal weight are required.

Due to the high compression forces and the sophisticated box design the balers produce uniform high-density bales.

The baling cycle is completely automatic, but all functions can be operated manually if desired.

The power units are equipped with the well-proven high-pressure axial plunger pumps with variable output, electrically controlled and hydraulically operated directional and relief valves, totally enclosed water-protected electric motors, oil cooling and oil heating systems.

The balers are very easy to operate and to maintain. All components are built to the highest standards and latest technology.

| | | | |
|---|---|---|---|
| bale size x.y | 300x300 (12"x12") | A | 2000 (79") |
| cycle per bale | 50 sec. | B | 1000 (39") |
| drive HP | 50 PS/HP | C | 800 (31") |
| lid force metric tons | 80 m.tons | D | 7000 (276") |
| pusher force metric tons | 100 m.tons | E | 3450 (136") |
| side force metric tons | 100 m.tons | F | 2800 (110") |

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# Fig. 2.13 Three compressions scrap baling press

**with compression lid, equipped with knives on one side**

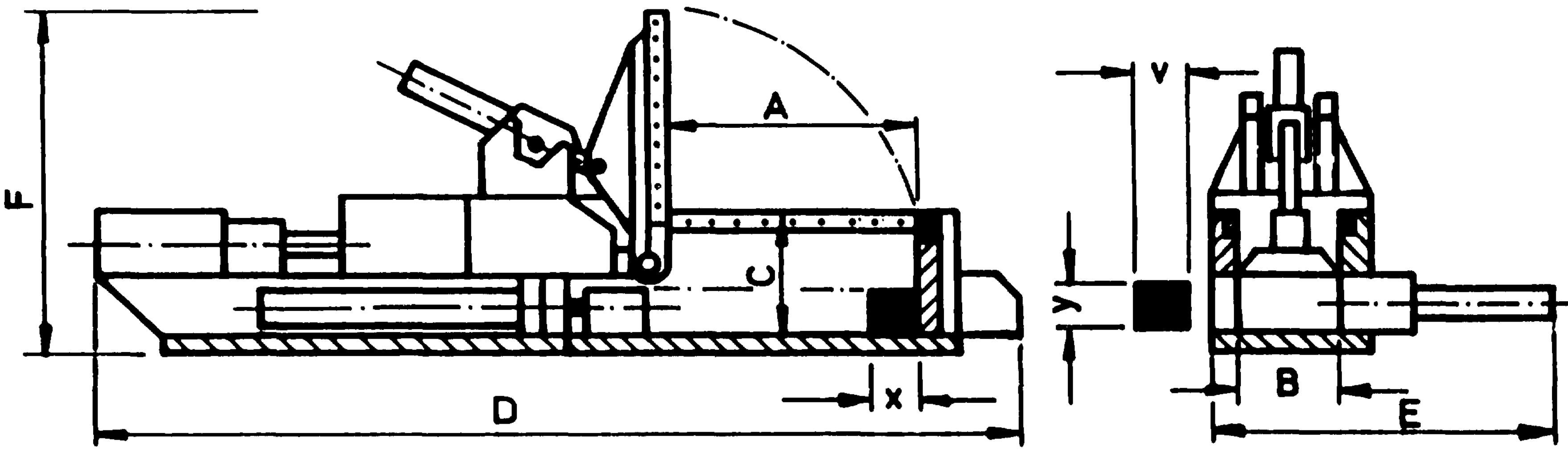


Fig. 2/14 shows a mobile model equipped with a feeding crane.
Crane and baling press are hydraulically controlled and driven by an electric motor.
(Electric motor, switch box, hydraulic valves, cylinder for upper compression ram with shear knives to cut overhanging material off, cylinder for side eject).
This baling press is manually controlled, equipped with necessary safety devices.

Finally Fig. 2/15 shows a stationary model of the same type we have seen before.

This picture gives a good impression of the difference between untreated scrap and the bales with a density of approximately 800 kg per m3 ready for charging.

**Fig. 2.14**

HYDRAULIC SCRAP BALING PRESSES

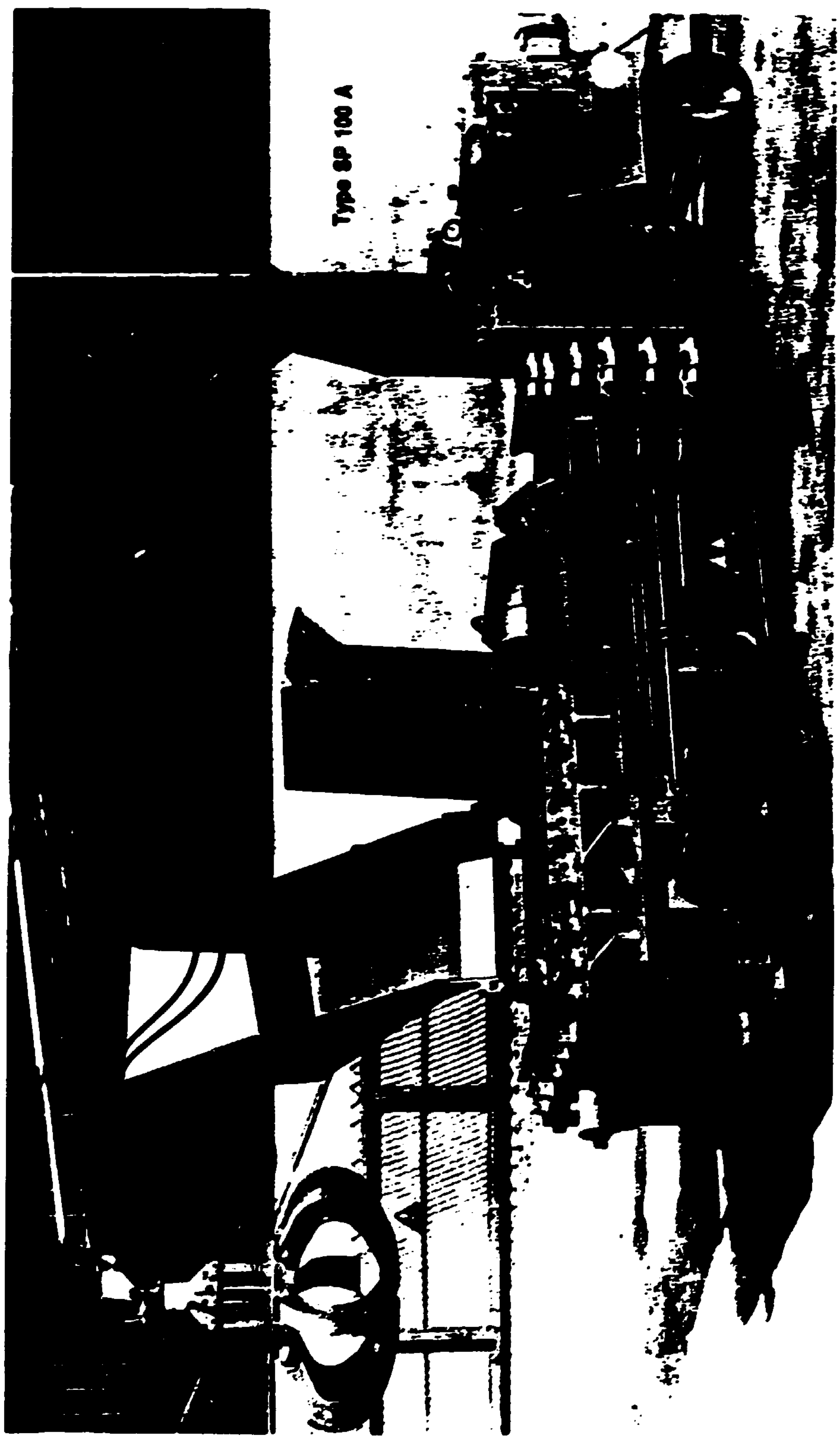
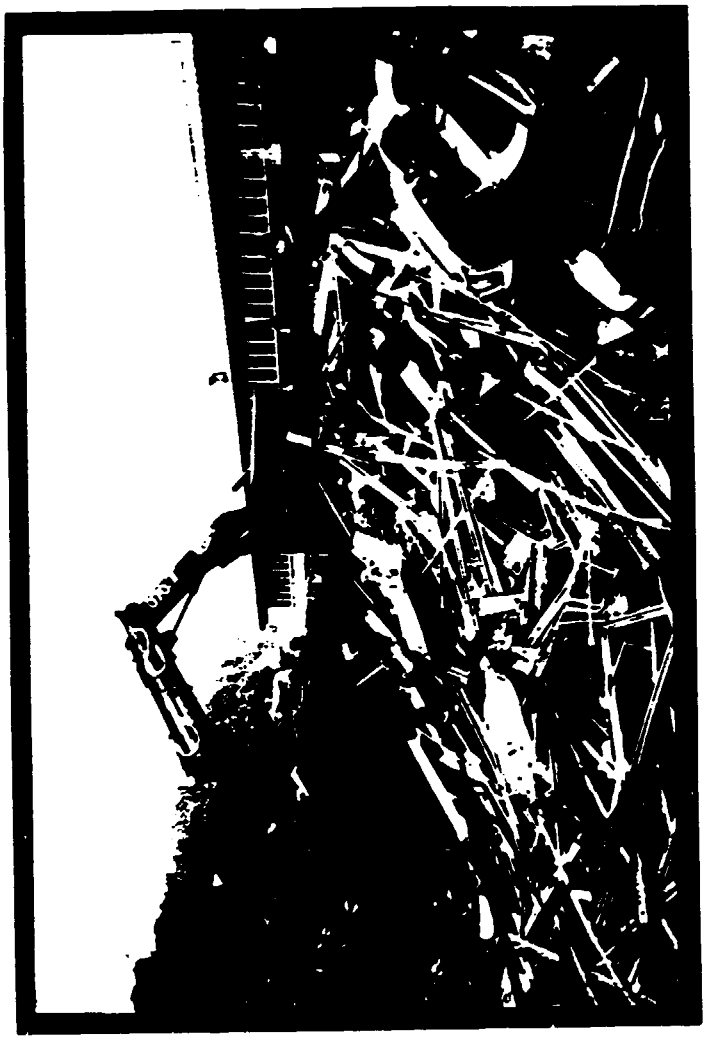


Fig. 2.15



# 3. Role of Technical Services for Steel Plants & Rolling Mills

## 3.1 General Considerations and Maintenance Strategies

To begin with, we should generally consider the organisation of a steel plant.

A basic organigram is shown in Fig. 3/1.
I would like to point out that this organigram is independent of steel plant capacity and number of staff and should be independent of the national and political influences.

A clear organization is important and one of the preconditions of successful operation.

The managing director is responsible for three departments:

**Production**
Manager/steel plant, Manager/rolling mill, Manager/technical services

**Administration**
Finance, Marketing, Sales, Procurement

**Quality Control**
Quality control department must be independent of production as far as the international standards and laws are concerned

**The duties of the managers should be as follows:**

Manager/Steel Plant:
Scrap yard, steel production, refractories

Manager/Rolling Mill:
Rolling mill Production, shipping

Manager/Technical Services:
Energy supply, mechanical workshops, maintenance

### General consideration of maintenance

Maintenance is important to the successful operation of any steel works, regardless of size.
Successful operation means:
- high productivity
- low breakdown time
- high product quality and
- competitive product prices.

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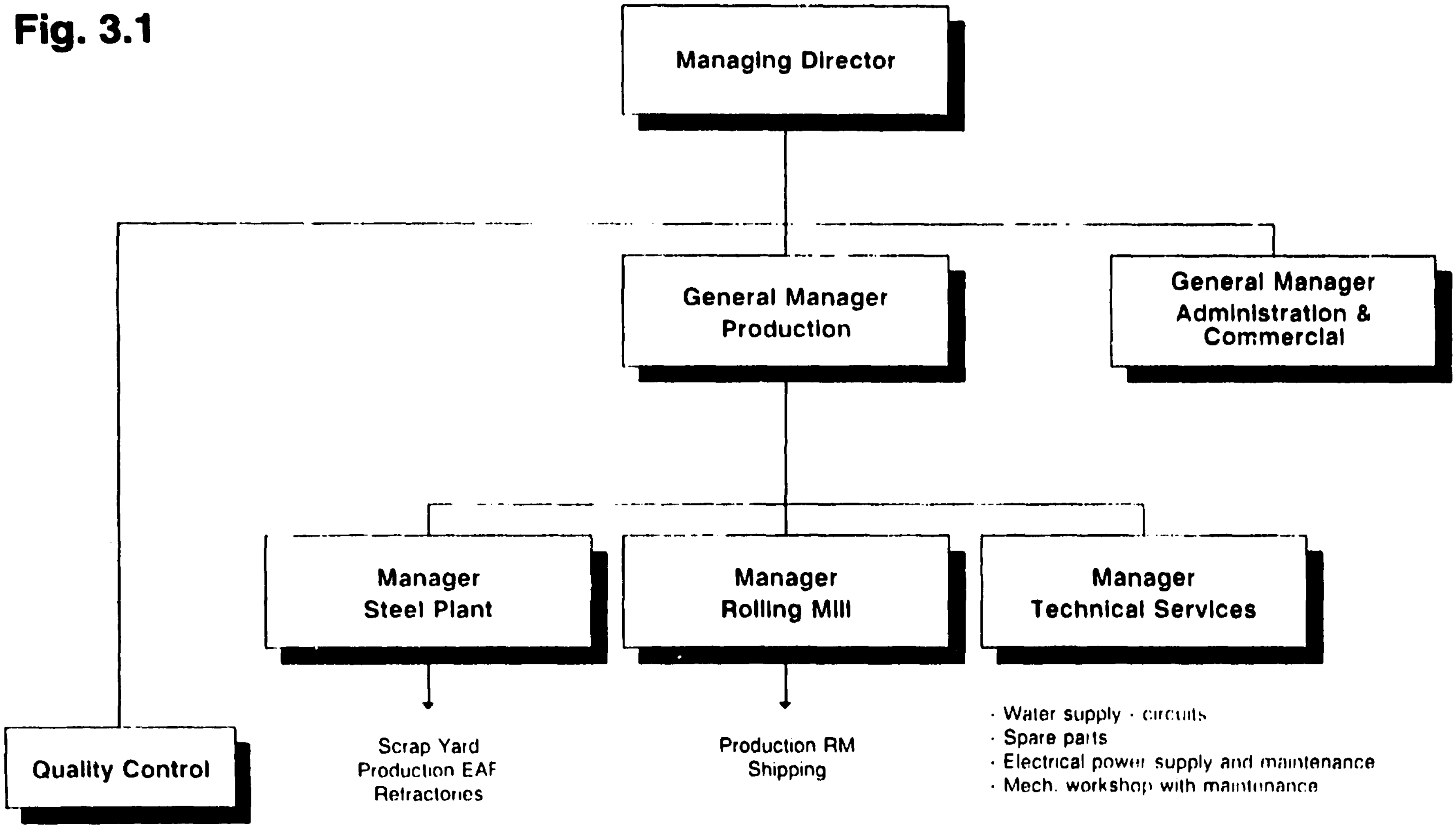
Organization:

**Fig. 3.1**



To achieve these objectives different strategies and methods for maintenance were developed.
Figure 3/2 illustrates the changing strategies for maintenance in European steel plants.

Before 1950, the concept was Breakdown Maintenance where a plant was repaired when problems occurred.

After 1950, the Breakdown Maintenance was rapidly replaced by Time-Based Maintenance, where plants were repaired on a time or tonnage basis; this period was the time of preventive maintenance.

Time-Based Maintenance remained the main maintenance method until 1970, when the rapid development in electronics and computing saw the arrival of Condition-Based Maintenance, where part replacement depends on data from sensors located on the equipment or on a check made by technicians.

In practice today, the following mixture prerails in Europe:

10 % BDM
40 % CBM
50 % TBM

This is an economical mixture. Nevertheless the maintenance costs in Europe vary between 8 and 15 % of steel works turnover, of which approximately half of these costs are for manpower. Maintenance costs are the third highest cost item after raw materials and manpower.

What can we transfer from European steel plants to PTA-Country steel plants:

## 1. Technical Services

Each steel plant - independent of production-capacity - should have a department called technical services.

The detailed tasks and responsibility should be as follows:

- Planning and engineering of all investments

- Full participation of maintenance people in design, selection and installation of steel plant equipment with reference to technical standards is important

- Plant maintenance, including workshop for repairs, manufacturing of tools, utilities and spare parts manufactoring

- Spare parts handling, storage, procurement and repair of spare parts

- Energy supply and distribution, electrical energy, cooling and drinking water, fuel, gas, compressed air

## Fig. 3.2 Concepts and methods for maintenance

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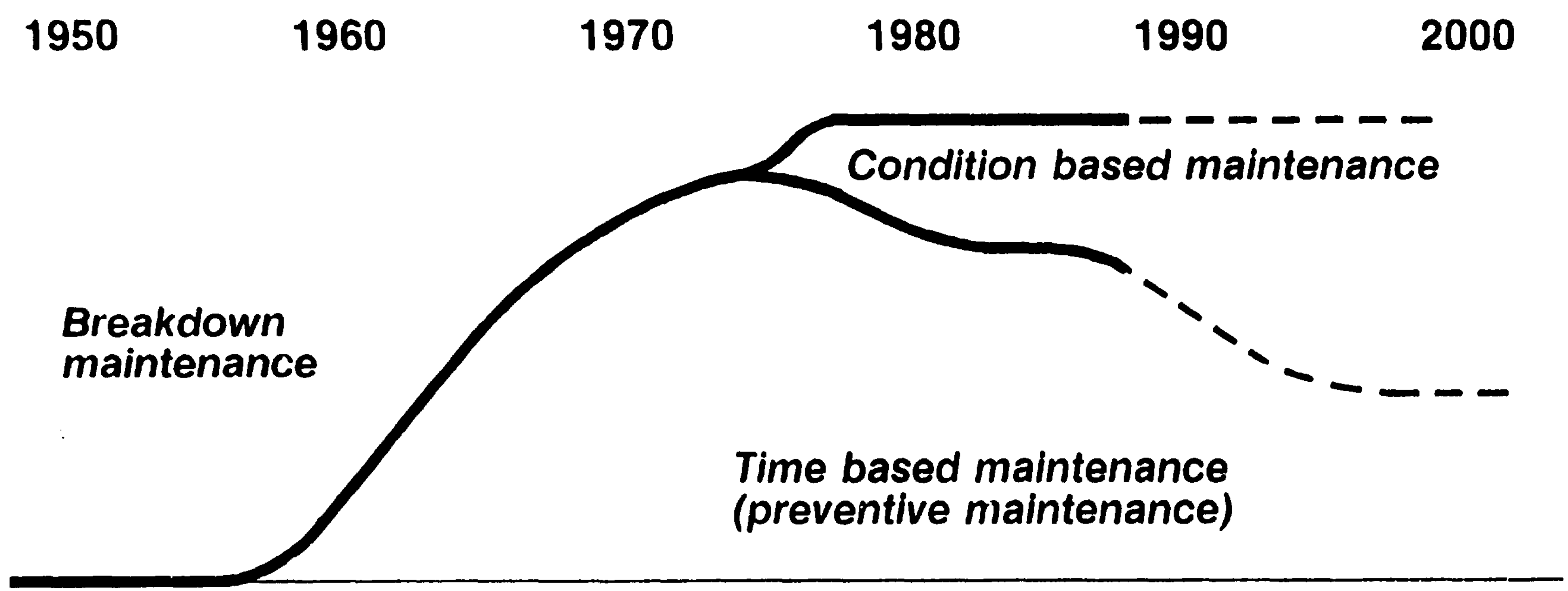


- Transport systems, cranes, belt conveyors.
The manager of this department should be a graduated engineer (mechanical or electrical); he is equivalent to the manager/steel plant and manager/rolling mill. A number of skilled fitters, welders and electricians are essential.
The number of staff members depends on the plant production capacity. We found that with a RolMil capacity of 10.000 t/year, a staff of 3 fitters and 2 electricians should be sufficient.

## 2. Maintenance strategy

For plant maintenance a strategy and a method should be introduced.
For large scale steel plants there are computer-aided maintenance systems available; for small steel plants these systems are too expensive and not necessary.

Maintenance should be done in following steps:

1) Maintenance, lubrication, cleaning, adjustments with reference to a lubrication chart or diagramme

2) Condition-monitoring of the technical equipment of the plant. Checking mechanical drives, cranes, electrical equipment, but also buildings, doors, and all the other off-sites

   A lot of monitoring techniques are used, e.g. vibration measurement, thermography, lubricant quality check, ultrasonic inspection, stress head check ...

   Monitoring must be based on a strategy. This is one of the duties of the technical-service engineer.

3) Repair is the last step in maintenance. Repairs should be determined by the outcome of condition monitoring. Breakdown maintenance should be the exeption rather than the rule.

## 3.2 Reheating Furnace Improvement

This type of furnace is an important part of a rolling mill productio line. It is important with regard to metallurgical aspects as well as production costs and fuel consumption.

The usual design of a reheating furnace for capacities from 2 to 10 t per hour is shown in Fig. 3/3.

On the right hand the material input:
The blooms or billets (150 mm square) will be pushed into the furnace by means of hydraulic or mechanical pusher.
This pusher is synchronized with the discharging pushing ram which is situated on the material output side.

After a hot billet is discharged, the ram on the input side will push the next billet into the furnace.

The flue gas coming from the burners is in back run to the billets. The flue gas leaves the furnace by this hole, passes through a recuperator and enters the chimney.

Generally we are speaking about a preheating zone with temperature levels from 400 to 800 °C and a heating zone with 800 to 1300 °C.

The heat transfer in heating zone is a result of heat radiation while in the preheating zone of heat convection prevails. This is also the reason for the shape of the furnace.

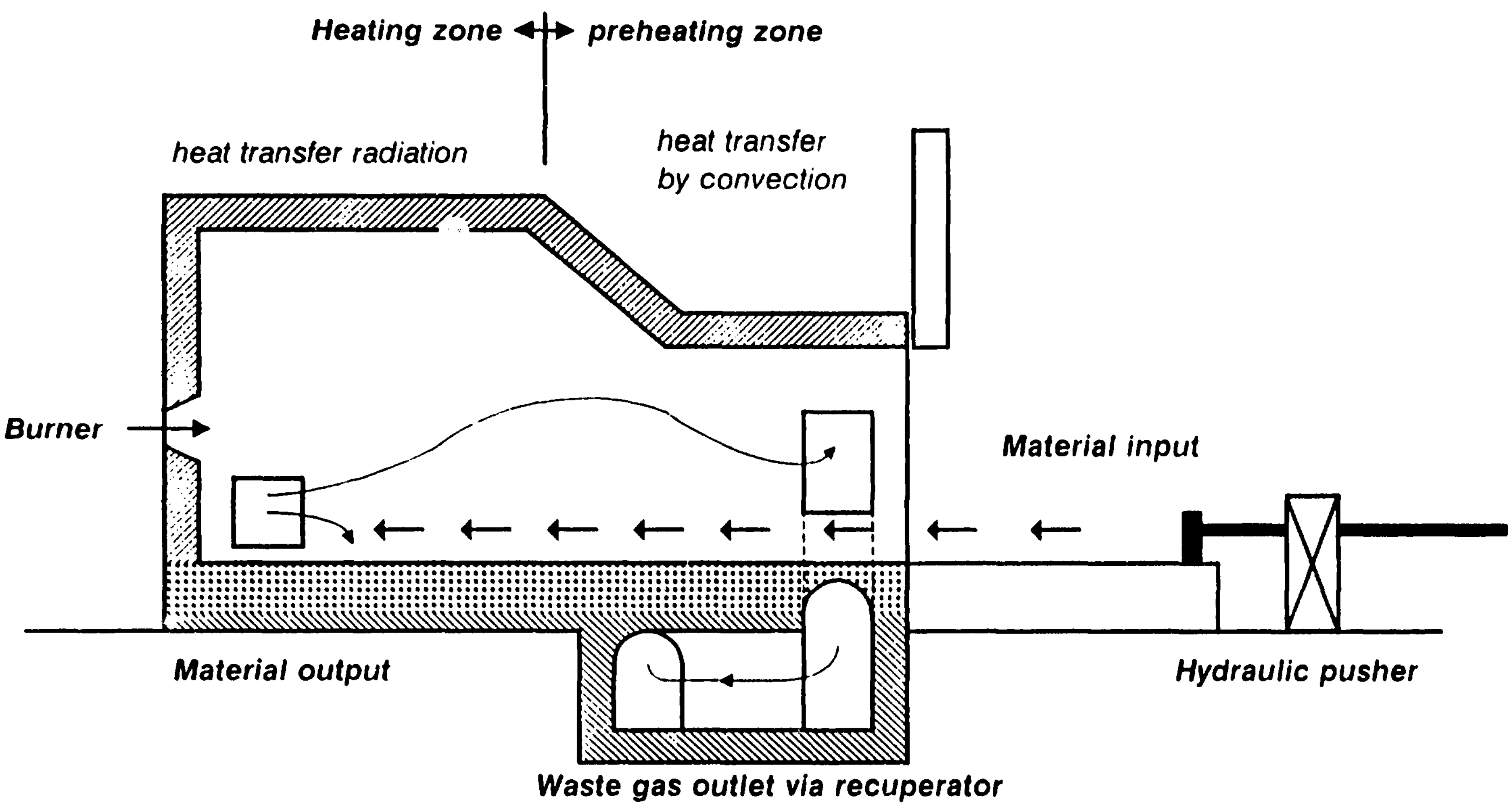
I want to point out, that the difference between the surface temperature of the billets and the temperature in the center of the billets should be less than 20 °C.

This is important for the quality of the final product and requires measuring instruments and a well-operating automatic furnace control system.

The lining of the furnace (walls and roof) should be constructed of bricks with the following characteristics:

| | | | |
|---|---|---|---|
| Heating zone | Classification temperature (ASTM) 1620 Centigrade | | |
| | Bulk density | 1040 kg/m$^3$ | |
| | Chemical analysis | Alumin<br>$Al_2O_3$ 73% | Silica<br>$SiO_2$ 24% |
| Preheating zone | Classification temperature | 1250 °C | |
| | Bulk density | 730 kg/m$^3$ | |
| | Chemical analysis | Alumin<br>$Al_2O_3$ 35% | Silica<br>$SiO_2$ 60% |

## Fig. 3.3 Reheating furnace



For the insulation layer for roof and walls:
Ceramic fiber base plates are prefered for the heating and preheating zones, or refractory castables for the wall.

Because of the billet movement, there is a thermal load as well as a wear load on the furnace bottom.
We recommend 96% magnesia bricks or better chrome corundum-bricks for the hearth.
The chrome corundum bricks are slag repellent and have an enormous resistance to mechanical damage and abrasion, especially for furnaces without skid rails.
The price is high, but these bricks ensure great economy, because care of hearth and repairs are reduced to a minimum.

Another important part of the furnace equipment is combustion control.

This is significant with regard to fuel consumption (the fuel price in PTA countries is high and you have to spend foreign currencies).

Fig. 3/4 shows combustion control equipment. This is the minimum equipment which should be installed.

Burner
Reheating Furnace
Recuperator for preheating the combustion air
Blower for combustion air
Stack

For exact combustion conditions you need flue of fuel and flue of combustion air. The ratio (proportion) of fuel to air is significant for combustion temperature T1 and composition of flue gas.

For normal operating conditions we recommend a ratio of 1 kg fuel to 12 to 14 m3 combustion air. Values beyond these values are typical for bad combustion, high fuel losses and poor economy.

The fuel flow, liquid quantity will be measured by a rotary-pistom-meter, a simple instrument, connected with a quantity indicator/recorder and quantity preset register.

The air flow will be measured by means of a primary differential pressure device, an electric transmitter and quantity indicator/recorder.

Watching the fuel flow and air flow readings, you may be able to control combustion quality by hand.

It is also possible to achieve automatic combustion control by means of a small computer.

We also have six thermocouples in our system:

1. heating zone
2. preheating zone
3. flue gas temperature recuperator inlet

**Fig. 3.4**

# Combustion control

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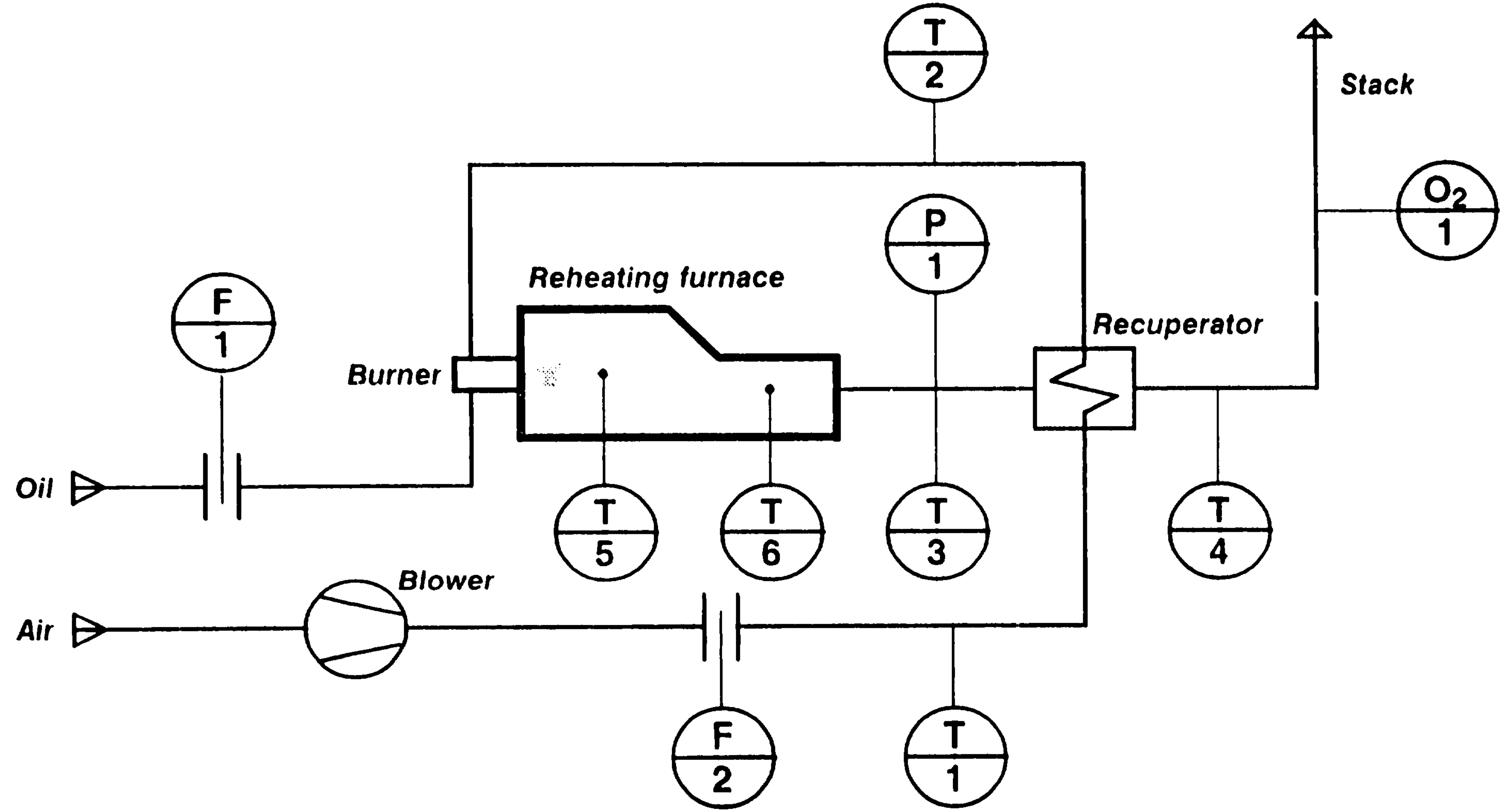


4. flue gas temperature recuperator outlet
5. combustion air temp. rec. inlet
6. combustion air temp. rec. outlet

Last but not least, an oxygen analyser should be installed in the flue gas channel. The oxygen content is critical for combustion quality.

The fuel consumption (oil) should be in a range between 350 and 520 kWh/t or 42 and 62 l fuel/$_t$ through put.

The oil consumption of the RolMil-Kenya pusher furnace was 80 l/t before our fact-finding missicn. Now the consumption is 60 l/t after installation of the recuperator. We are convinced that oil consumption can be decreased to 50 l/t if monitoring equipment - as described above - is installed.

## 3.3 Cooling Water Circuits

Wherever steel is produced there is the problem of extracting heat from the electric arc furnace, furnace-transformer, pusher furnace and other facilities of the steel-making process.

The use of fresh water for cooling in an open air circuit is too costly. Beyond that, good fresh cooling water is - especially in your countries - not available in sufficient quantities.

The alternative is the use of air, free and available everywhere. The air recools the water, which runs in a closed circuit and is heated in the process.

Two systems are common:
Cooling-tower or cooling-pond system
Air heat exchanger

**Cooling Tower** (Fig. 3/5)

In a cooling tower the fresh water is cooled with air mainly through evaporation. There are many different designs for such towers, but the basic principle is the same for all. Cooling is achieved by air that comes in direct contact with the water, and thus part of it is continuously lost through evaporation. Most cooling towers use fans but some big towers are designed for self-circulation of the air.

The cooling pond-system, used by RolMil Kenya, also involves cooling by evaporation.

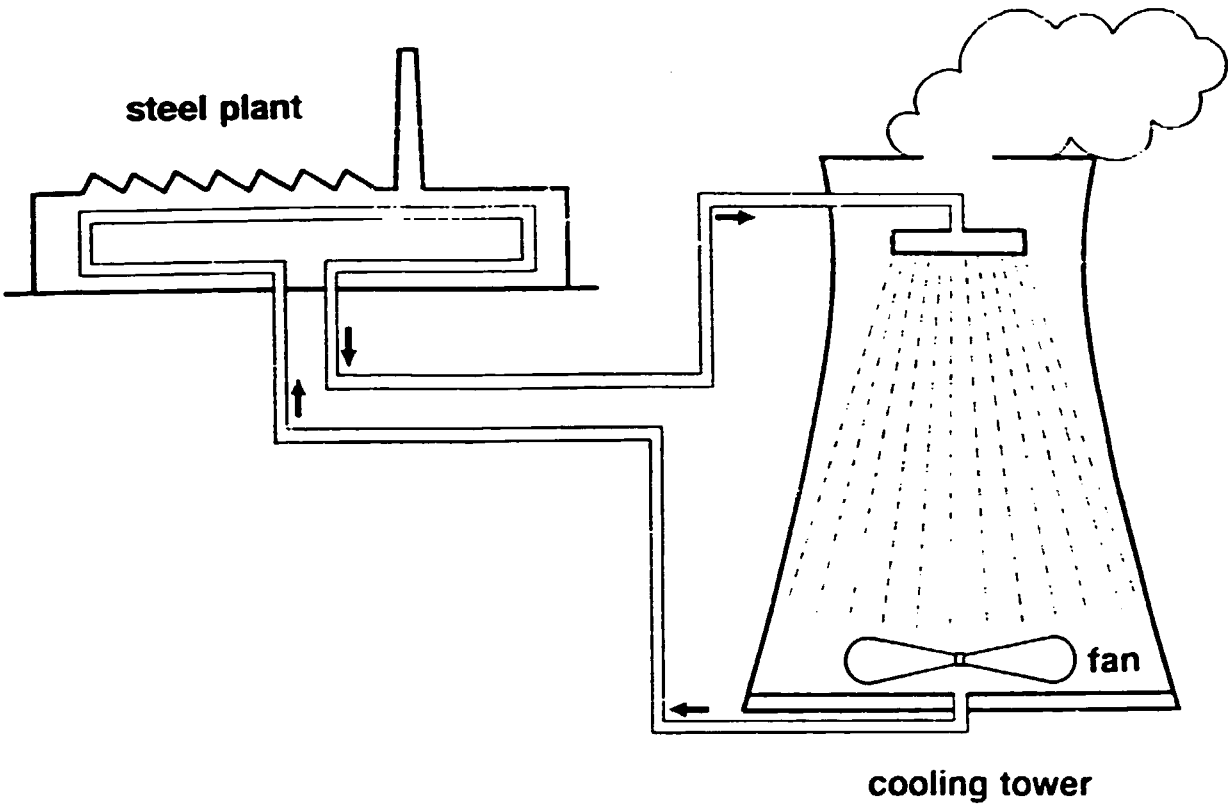
Instead of a cooling tower a cooling pond is used.

The investment costs of cooling-towers or cooling-ponds are not high.
Due to evaporation and the continuous drain to avoid excessive concentrations of minerals and dust, 5% or more of the circulating flow <u>must</u> be continuously added. The costs for this treated make-up water can be quite substantial.

To avoid oxygen in water causing corrosion, chemicals <u>must</u> be added.
Additional chemicals must also be added to compensate for the acidity which is caused by sulphur dioxide in the air. Other reasons for additives are for example to eliminate marine growth in the equipment or prevent rotting if wooden towers are used. The advantage of using a cooling tower is that no large amount of secondary water is required, but the make-up water that is continuously added has to be of high quality. A cooling tower is normally rather bulky and thus requires a great deal of space, especially the large hyperbolic towers. They also have a negative effect on the environment because of plumes.
The use of cooling towers is usually justified when the air is pure and clean and fresh water with low mineral content is available as make-up water.

# Cooling-tower System
(open circuit)

**Fig. 3.5**



**Air heat exchangers** (Fig. 3/6)

Cooling the circulating fresh water indirectly by using air in heat exchangers is advantageous because no secondary water is required and there are no restrictions in heating air. Some air heat exchangers are designed in standard modules, which makes it easy to increase the size of the heat exchanger if and when necessary. As the water circuit is closed, make-up water is not needed.
Due to the low heat transfer coefficient, however, an air heat exchanger is always very bulky and thus requires a large space. The latter factor is of minor importance if, for instance, the air heat exchangers can be installed on the roof of a building. However, as the units are heavy, they require expensive foundations. Further an air heat exchanger is equipped with fans which are normally very noisy and often have very high power consumption. Air heat exchangers are thus an expensive investment, but their operating costs are moderate compared to cooling towers.

An alternative method for cooling the internal water circuit is shown in Fig. 3/7 and called water heat exchanger.

If secondary water is available, whether sea water, coastal water, lake water or river water, it can be used to cool the internal fresh water circuit in plate heat exchangers.

Some aspects of this system are:

**Material:** Titanium is fully resistant to sea water, brackish water, etc., even if it is very contaminated. Today it is possible to press plates of very thin material, which makes the price of a plate heat exchanger with all wetted parts of titanium only a little higher than a stainless steel unit for the same duty. This is one of the reasons why titanium plate heat exchangers are so extensively used today for cooling diesel engines on board ships with sea water.

**Cleaning:** One of the main features of the plate heat exchanger is that it can be fully opened for inspection or mechanical cleaning with only a few turns by hand.

Finally, the investment and operation costs.
Table 1 shows the approximate costs for installation and operation of the different systems.

**Comments on the table:**

The air heat exchanger has been calculated for an air temperature of 25°C (77°F).
The cooling tower has been calculated for air having a dew point of 22°C (72°F).
The make-up water for the cooling tower has been calculated with 4% evaporation, 2.5% of which is due to the evaporation as such, 1% of dilution water and about 0.5% of splashing losses.
For the pumping costs a pump efficiency of 80% has been used, the electric costs 1.5 US cents/kWh.
The time of operation is 8,000 hours per year.

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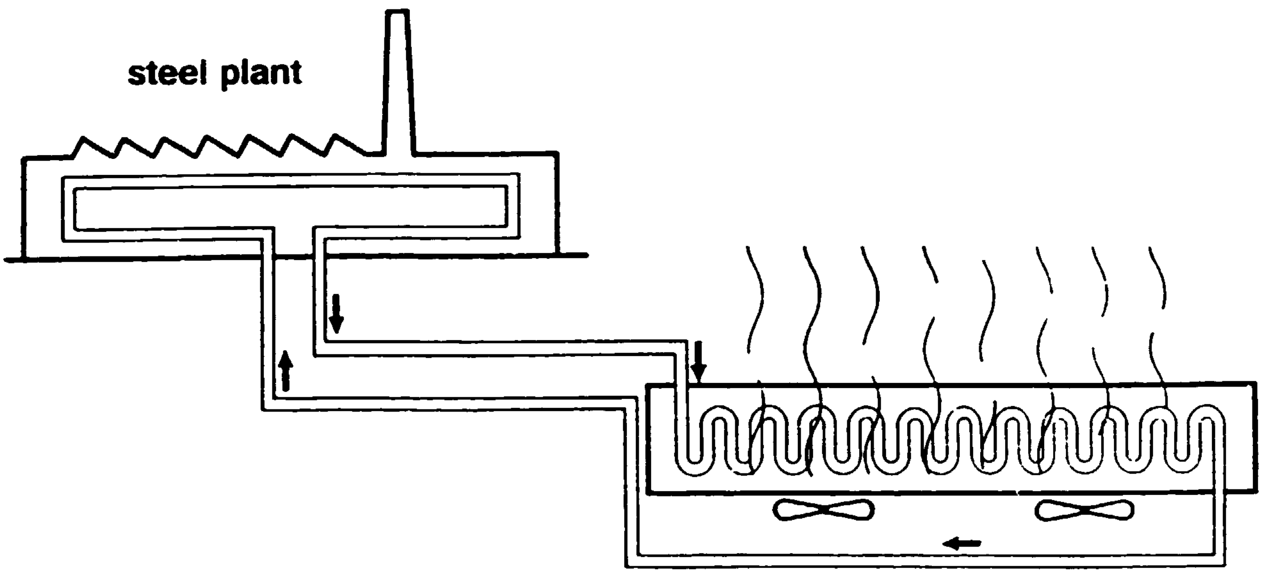
# Air heat exchanger
## (closed circuit)

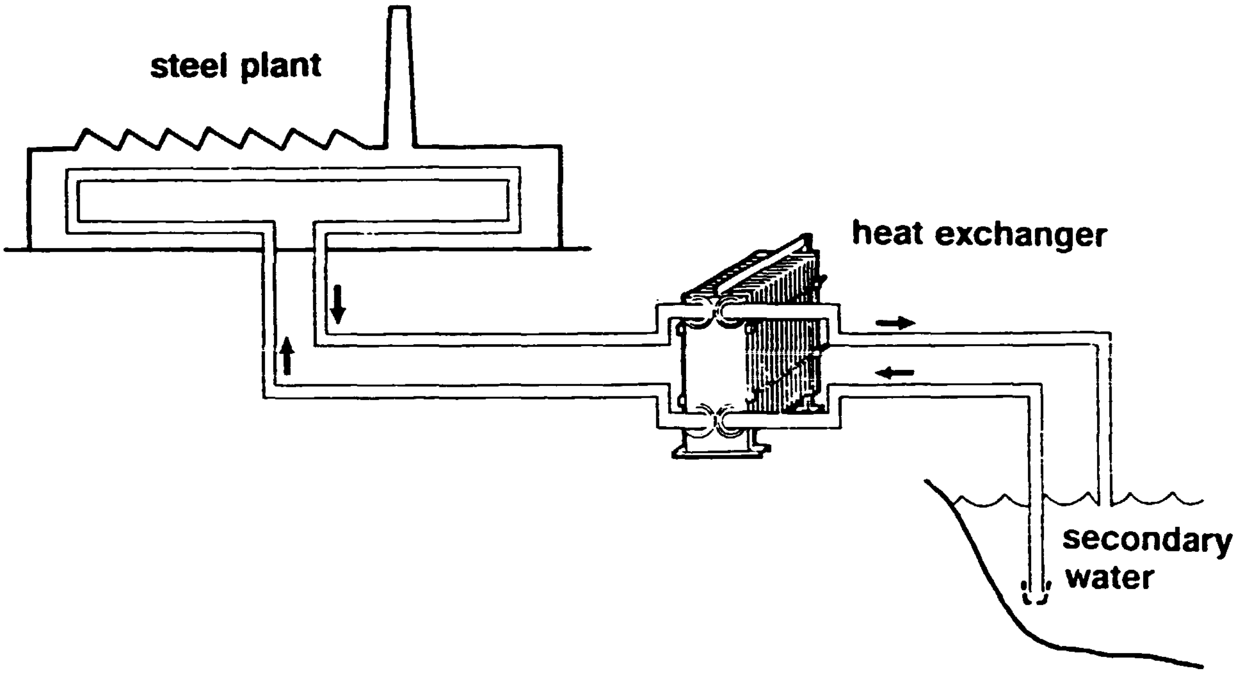
## Fig. 3.6

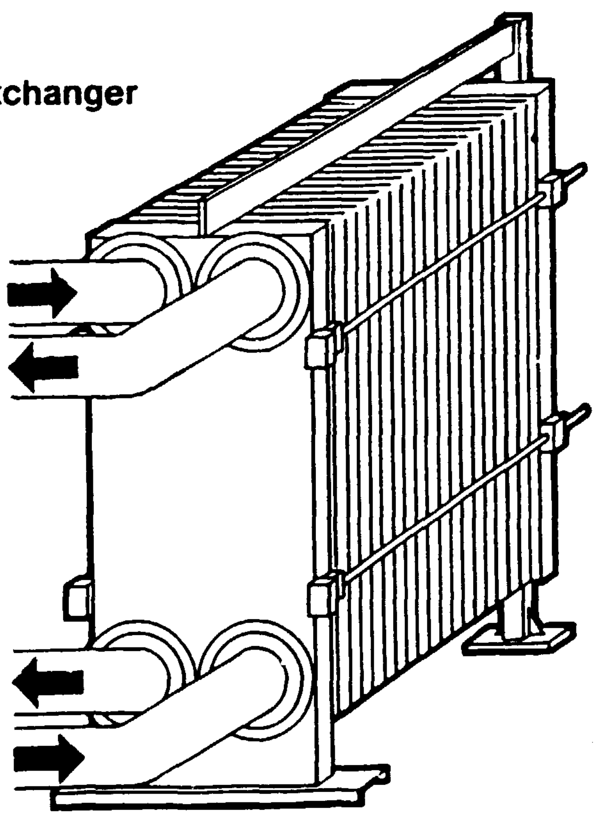


# Water heat exchanger

## (closed system)

## Fig. 3.7



The water heat exchanger is designed to consist of two plate heat exchangers calculated to use equal quantities of primary and secondary water; the secondary water temperature is 24°C (75°F). As the sea water is corrosive, titanium is used for all surfaces that come in contact with sea water. The fresh water is cooled from 45 (113) to 30°C (86°F).

In calculating the annual investment costs, five year's depreciation time has been used and an interest rate of 8%, which yields an average annual cost of 1.25% of the investment cost.

**Conclusion:**

If secondary cooling water is available and its use is allowed, the water heat exchanger is a very economical solution.

Open cooling tower and closed air heat exchanger system are equal from the cost-per-year standpoint.

We would prefer a closed circuit: you don't need additional make-up water and corrosion problems are minimized.

Table 1

COOLING CAPACITY 15X10 KCAL/H (60X10BTU/H), PRICES IN US DOLLARS:

| | | Air heat exchanger | Cooling tower | Water heat exchanger |
|---|---|---|---|---|
| 1. | Cost of cooling surface $\$/m^2$ ($/sq ft) | 120(11) | -- | 180(17) |
| 2. | Heat transfer coefficient kcal/$m^2$,°C,h (BTU/sqft,°F,h) | 650(130) | -- | 3.000(600) |
| 3. | Investment cost for equipment | 310.000 | 100.000 | 150.000 |
| 4. | Annual investment cost | 77.500 | 24.000 | 50.000 |
| 5. | Operation cost per year | 600 | 6.000 | 6.000 |
| 6. | Cost of make-up water per year | -- | 50.000 | -- |
| 7. | Total cost per year | 83.000 | 80.000 | 56.000 |
| 8. | Relative cost % | 100 | 96 | 66 |
| 9. | Floor space requirements $m^2$ (sq ft) | 800 (8600) | 100 (1080) | 20 (220) |
| 10. | Cooling water $\$/m^3$ | 0,055 | 0,053 | 0,044 |

## 3.4 Electrical Power Supply

There are no serious supply problems in electrical power for RolMill Kenya also no disturbances to the electrical network is reportet,but this may change from place to place.

Fig. 3/8 shows a typical "electric diagramme" for EAF installations for information

Concerning the EAF work in RolMill the following was found:

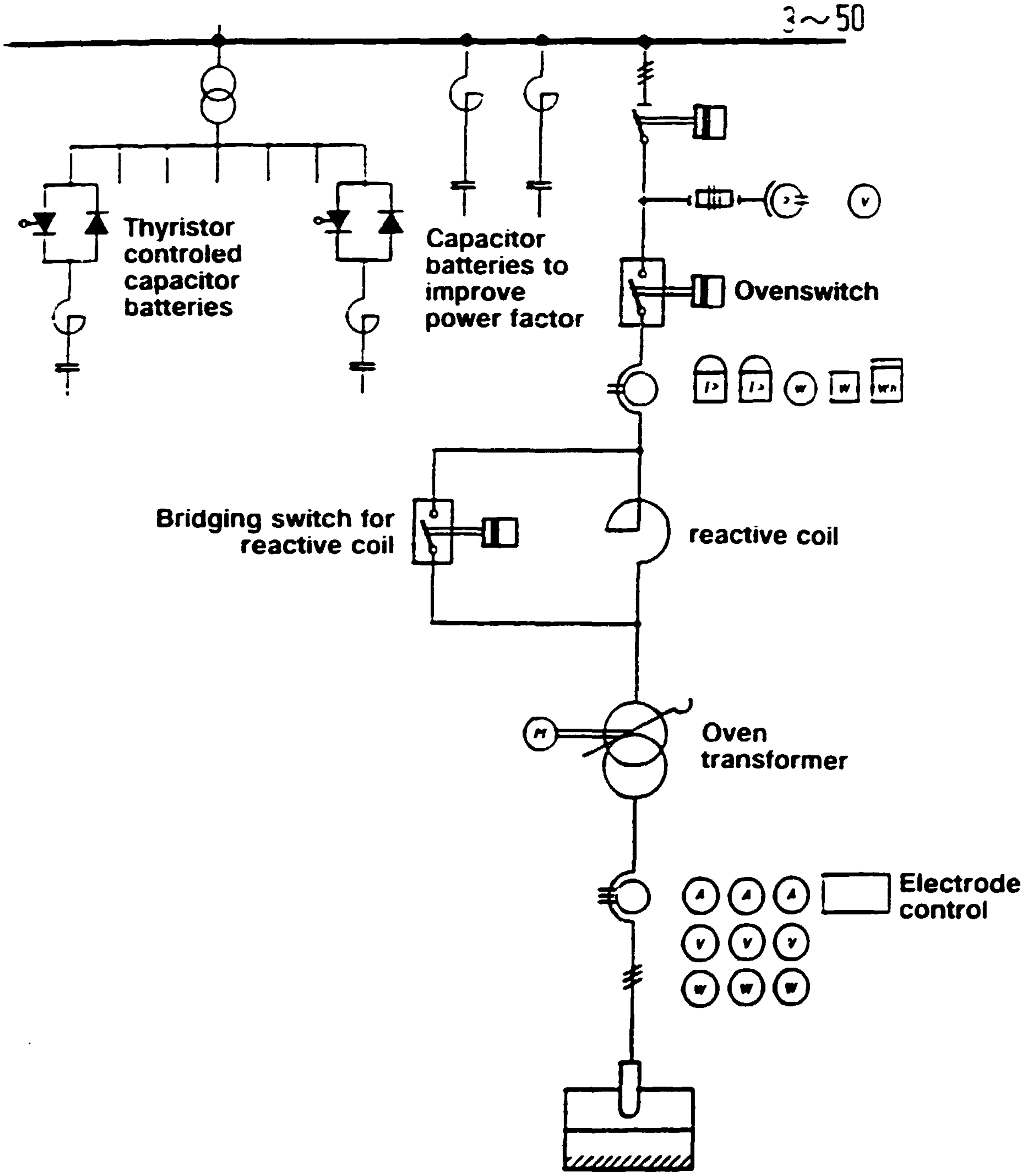
- The furnache works with extreme low inductivity which caused fluttering of the arc, especially during the melt down periode (when full voltage is constantly needed) and numerous tripping of the circuit breaker have been noticed.

**Actions/Recommendations:**

- The reactance (inductivity) of control equipment was increased to full value
- Installation of a inversed time relais was recommended to use the full transformer capacity under safe working conditions
- A better uniform scrap would allow an increase in electrical energy input and consequently reduce the melting time (15-20 min.)
- To increase the safety situation it was strongly recommended to lock all the doors for high voltage switch board and to change the solid doors of high voltage cabins by grid doors.
- Staff training of different levels was carried out (it has to be mentioned that qualification of electrical maintenance personnel was found quite above level)

# General diagram
# High voltage switch gear EAF

## Fig. 3.8



# 4. RolMil Kenya - Results and Improvement Potential

## 4.1 Input Summary

The Rolmil Kenya Rehabilitation programme started in 1989 after the project financing was settled between UNIDO and the Austrian authorities for technical co-operation. RolMil Management declared its willingness to realise, within its possibilities, such programme and experts' recommendations.

VOEST-ALPINE Industrial Services (VAIS) / Austria was charged with the realization of the project.

**On-Site expert services** summed up to a total of 35 manweeks of work including two weeks of fact-finding by

1 Engineer/Technical Services
1 Metallurgist

and a Technical Assistance Phase by

1 Engineer/Technical Services (6 weeks)
Metallurgist (6 weeks)
Engineer/Electrical Maintenance (3 weeks)
Mechanical Technician (10 weeks)
Electrical Technician (6 weeks)

The programme was supported by a 2-week orientation and training of the works manager in Austria. During the whole programme duration (1.5 years) continued support was given by VAIS home office (information gathering, equipment specification, requests for bids etc.)
Experts' main activities during their stay at RolMil are shown in fig. 4/1.B.
Concerning the methodology of work and project highlights, reference is made to chapters 1, 2 and 3 and the corresponding graphs and figures.

**Equipment Supply**

To ensure Rehabilitation programme success, investments as recommended by the experts were necessary and carried out by RolMil Kenya to a large extent adding up to approx. 10 mio. KSh. (fig. 4/1.A)
UNIDO supported the investment programme by supplying
- measuring and control device
- lab equipment and
- tools

The main objectives of these investments were:
- to improve scrap preparation
- to increase material handling capacity in the EAF shop
- to install equipment for injection of oxygen.

**Fig. 4.1**

# REHABILITATION PROJECT
# ROLMIL

## A SUPPLIES/INVESTMENTS

ROLMIL:

| | |
|---|---|
| PURCHASE OF | BALING PRESS<br>NEW CRANE<br>HEAT EXCHANGER<br>GEAR BOX F. ROLLING MILL |
| CONSTRUCTION | MECH:MAINTENANTE SHOP AND LAB. FACILITIES |

UNIDO:

| | |
|---|---|
| PURCHASE OF | CARBON & SULF. ANALYSER<br>TEMPERATURE MEASURING EQUIPMENT<br>TOOLS F. MAINTENANCE SHOP |

## B EXPERT'S MAIN ACTIVITIES:

- EAF PROCESS IMPROVED
- SCRAP PREPARATION IMPROVED
- CARB. & SULFUR ANAL. PUT INTO OPERATION
- TEMP. MEASURING EQU. PUT INTO OPERATION
- ASSISTANCE FOR INSTALLATION OF NEW CRANE
- ADJUSTMENT OF ELECTR: PARAMETER OF EAF
- TRAINING FOR:
  - MELTSHOP PERSONNEL
  - ELECTRICIANS
  - WELDER & FITTER
  - QUALITY CONTROL PERSONNEL

- to reduce fuel consumption
- to get quick and correct information about process temperature, carbon and sulphur content of steel

## 4.2 Programme Results

### Production increase

Since the start of the programme, main efforts have been directed towards increasing the production in the EAF shop. For 1991 RolMil expects an output of 10,500 t of good ingots corresponding to a production increase of approx. 15% (see fig. 4/2). Continuing its efforts, a production of more than 12,000 tons should be achieved in 1992.

Basis of these improvements were:
- better scrap preparation and
- modification of EAF Process by introduction of foamy slag technology together with injection of oxygen (process details are given in chapters 1 and 2)

The better scrap preparation is reflected by the reduction of buckets per heat from 7 to 4.5 (see fig. 4/3) and therefore reduction of tap-to-tap time and losses. There is still room for further improvement as the number of buckets has to be further reduced down to 2 to 3 per heat to meet international standards and reduce tap-to-tap time to 120 minutes. Under such conditions RolMil should produce 13,000 tpy with the existing EAF core-equipment.

### Savings

- Increase of EAF refractory lining service life.
  The improvements in process technology have not only reduced tap-to-tap time but have also led to remarkable increase in refractory life in the EAF.
  Fig. 4/4 shows that the "life time" of EAF roof and wall lining has practically doubled during the programme period (until July 91) !!
- Decrease of electrode consumption by 25%
- Decrease of specific fuel consumption for reheating furnace
  The recommended installation of the recuperator and new burners led to a reduction in specific fuel consumption in the reheating furnace by about 25% which is in the range of about 50 lt per ton of steel ingots (see fig. 4/5). A further decrease could be obtained by installation of adequate measuring and control equipment (see chapter 3.2)

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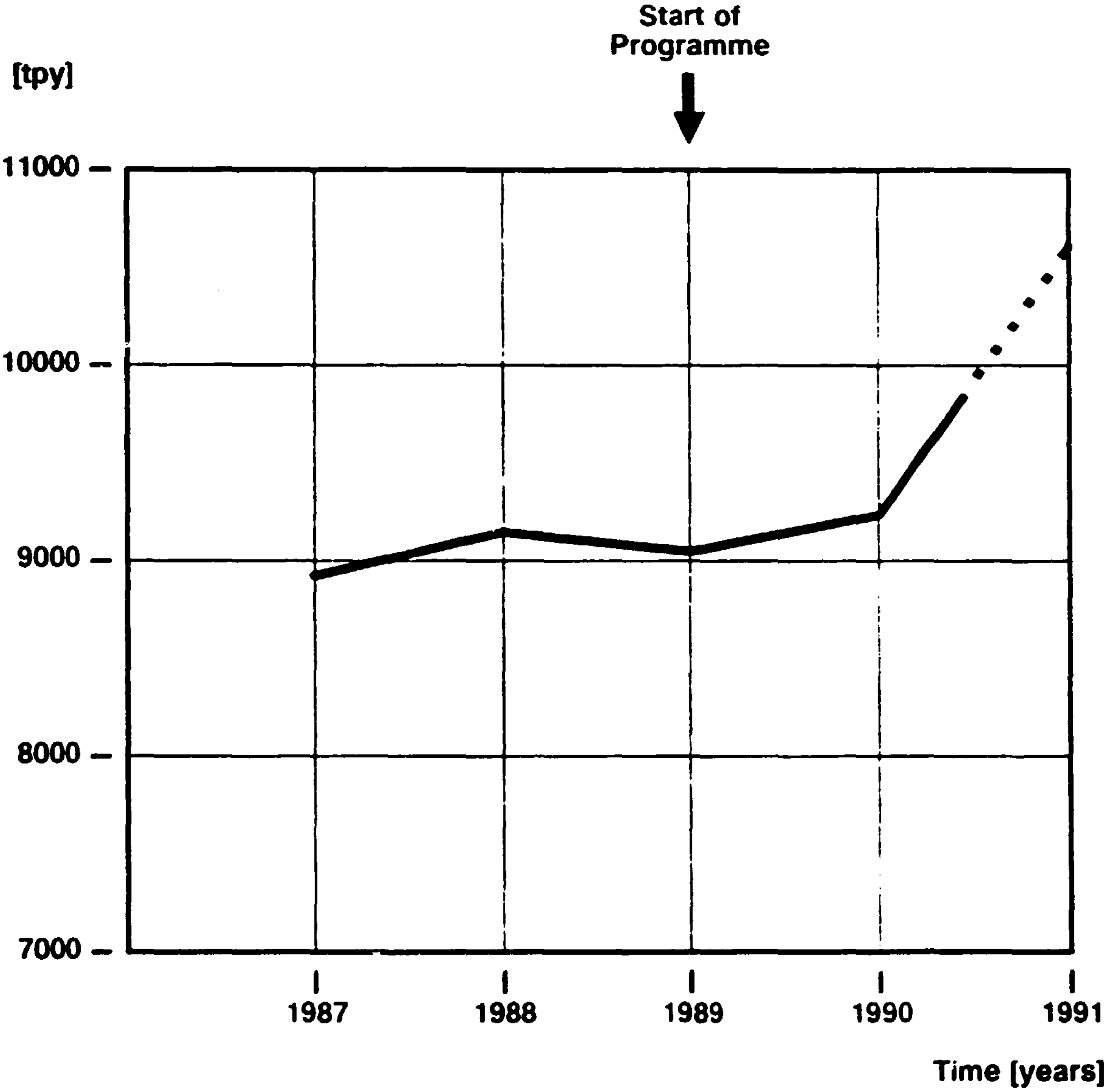
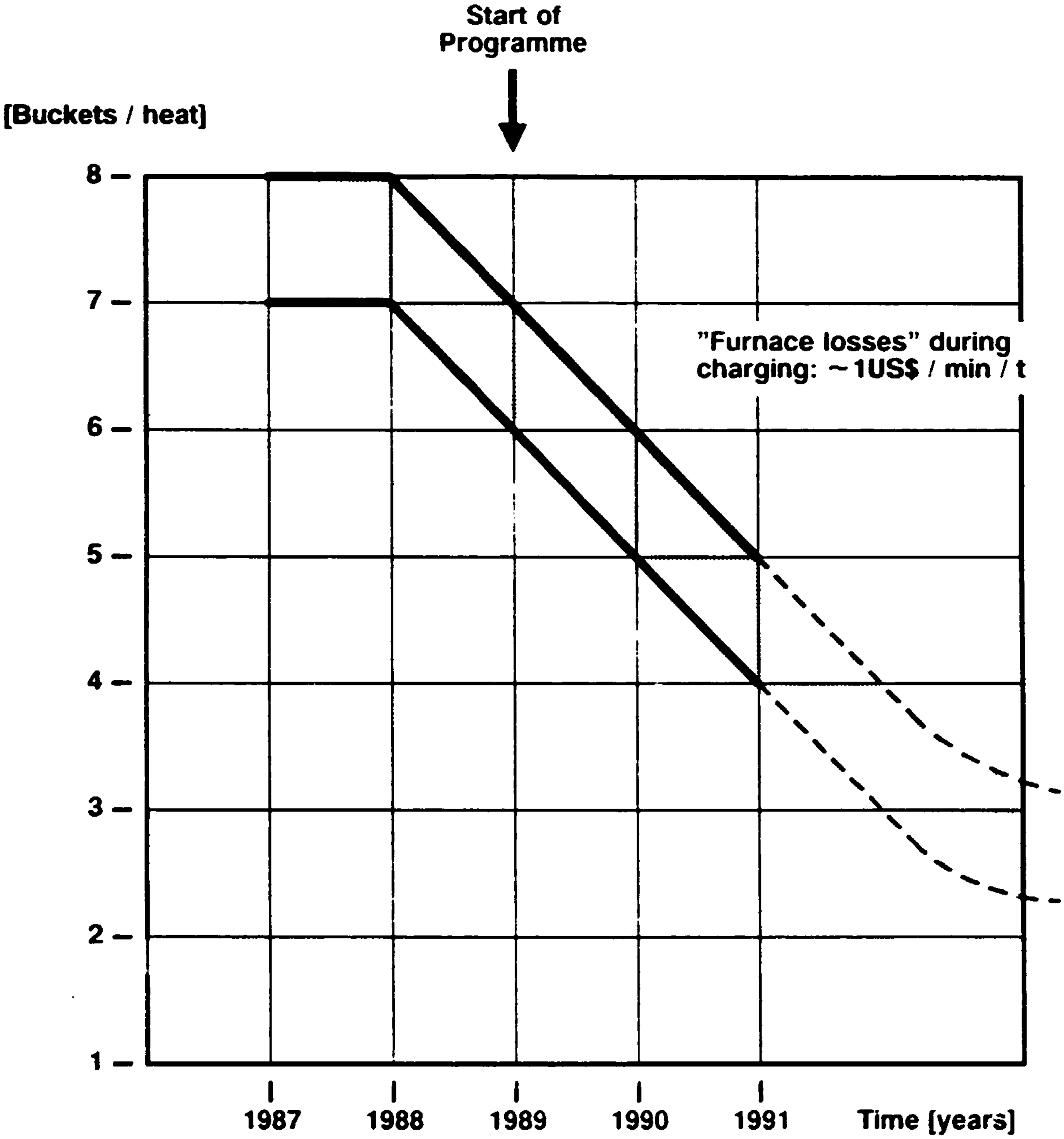
# Fig. 4.2 Rolmil Production Development
## (good "pencil ingots")



# Fig. 4.3 Reduction of Number of Buckets / Heat



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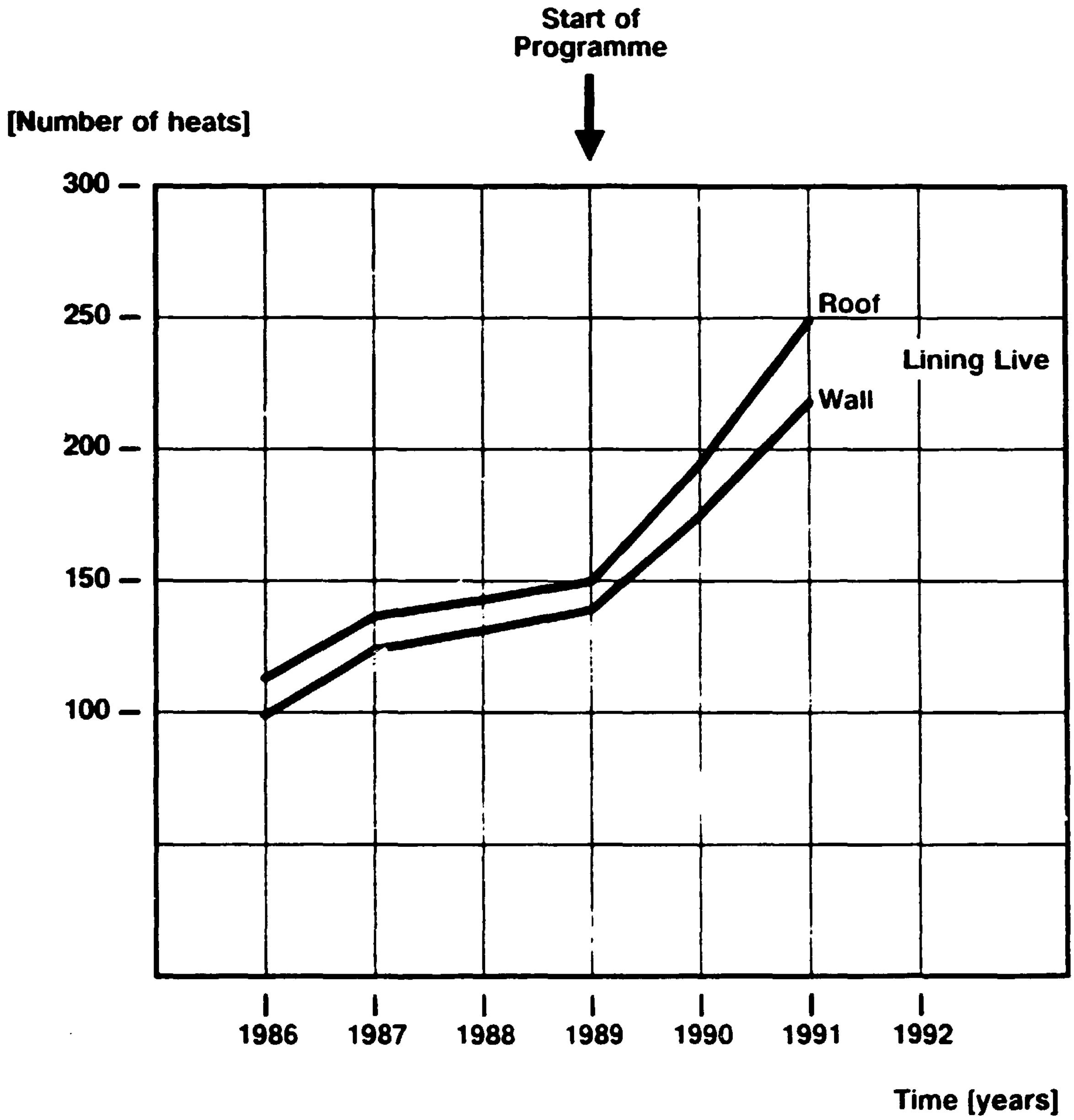
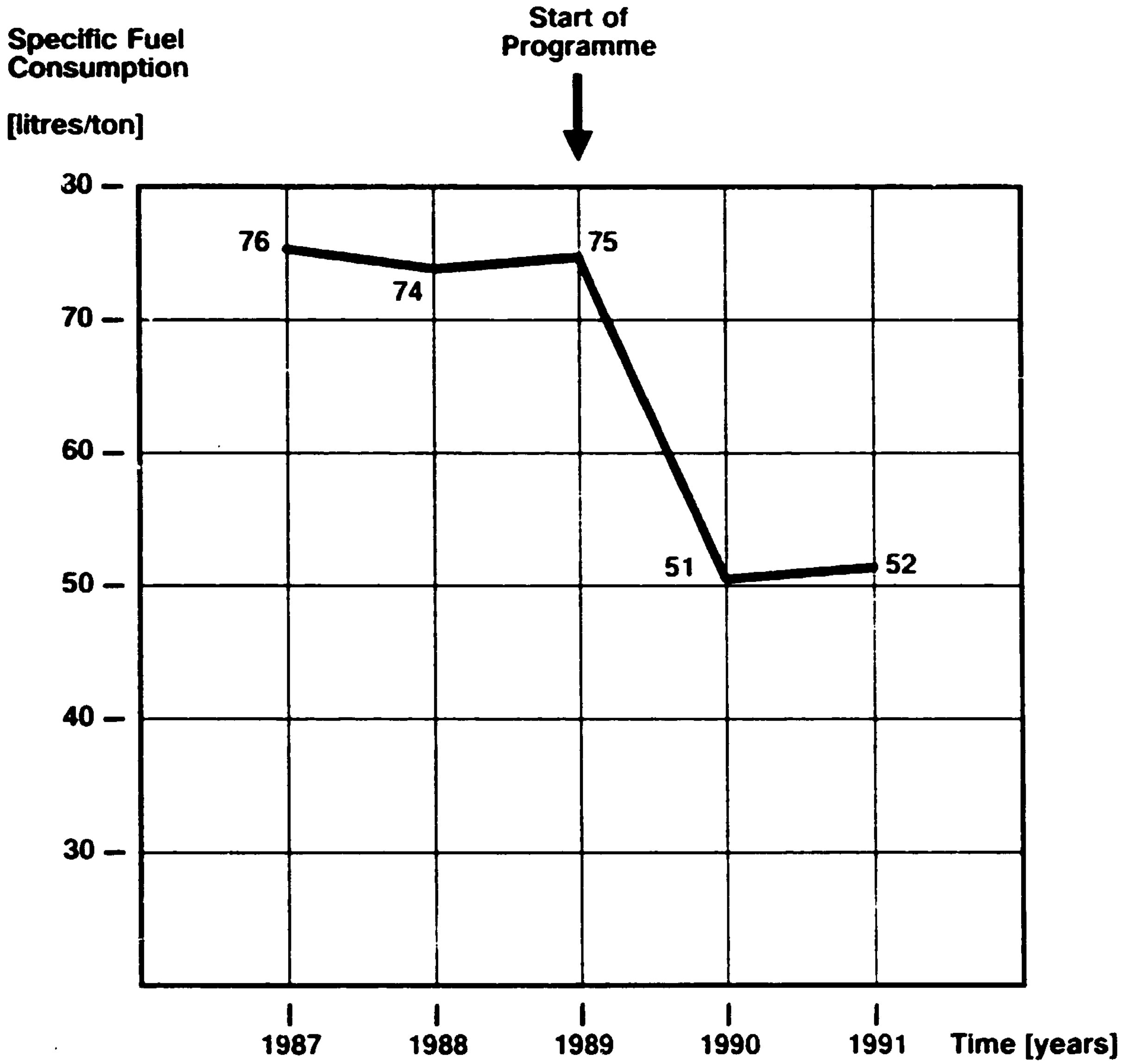
# Fig. 4.4 Development of EAF Roof and Wall Lining Life



# Fig. 4.5 Reheating Furnace

## Development of specific Fuel Consumption

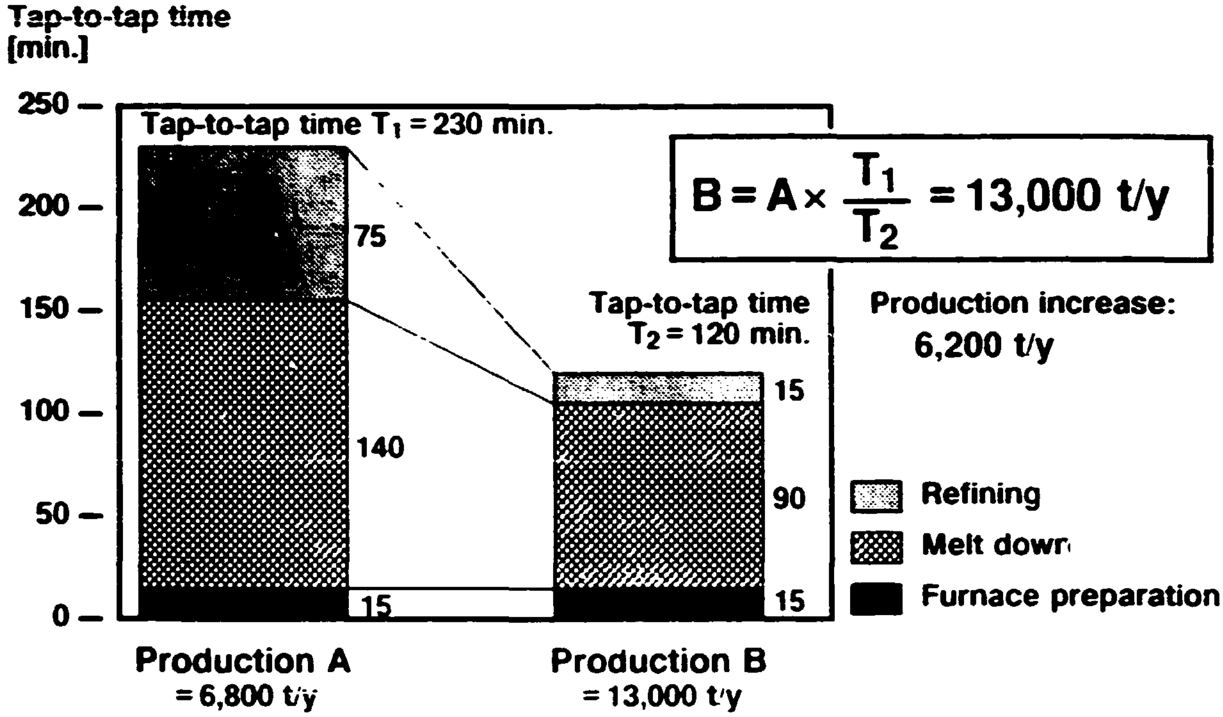


## 4.3 Feasibility of Continued Rehabilitation Programme

Basic considerations on rehabilitation programme feasibility in an EAF shop similar to RolMil are given in fig. 4/6.
The chosen example presumes that the EAF shop with a 6 t furnace and 2.4 MVA transformer runs with a tap-to-tap time of 230 minutes.
By means of investments (basically for scrap preparation and analysing equipment) and process adaptations the tap-to-tap time shall be reduced to 120 min. representing a production increase of 6200 tpy. The example shows in a quite simplified way that pay-back periods of 2 to 2.5 years are feasible considering only the surplus of earnings resulting from increased production.

# Fig. 4.6 Feasibility Aspects of Rehabilitation Programmes (in an EAF Melt Shop)

## 1. Technological Adaptions:




$$B = A \times \frac{T_1}{T_2} = 13{,}000\ t/y$$

Production increase:
6,200 t/y

## 2. Preconditions and Investment Costs:

### Preconditions to achieve target goals:

- improved scrap preparation (2 buckets/heat)
- use of oxygen during melting and refining
- "ladle alloying" during tapping

### Investment costs:

| | Cost in US$ |
|---|---|
| Scrap shear .......... | 25,000 |
| Scrap press .......... | 67,000 |
| Mobile crane ......... | 60,000 |
| Weighing equipment ... | 12,500 |
| Spectrometer ......... | 84,000 |
| Other devices ........ | 17,500 |
| Subtotal ............ | 266,000 |
| + Import of duties .... | 530,000 |
| Assistance programme | 150,000 |
| Total ............... | 680,000 |

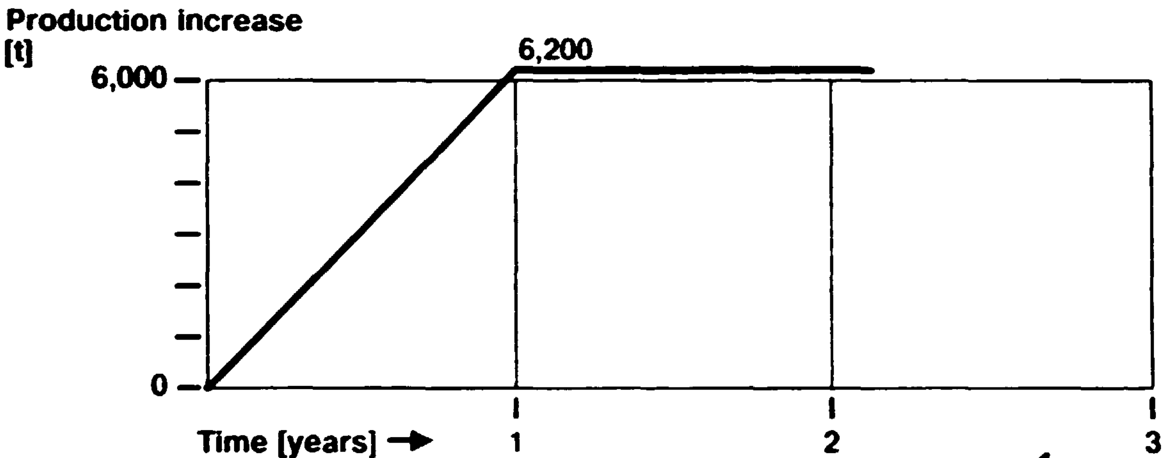
# Fig. 4.6 Feasibility Aspects of Rehabilitation Programmes (in an EAF Melt Shop)

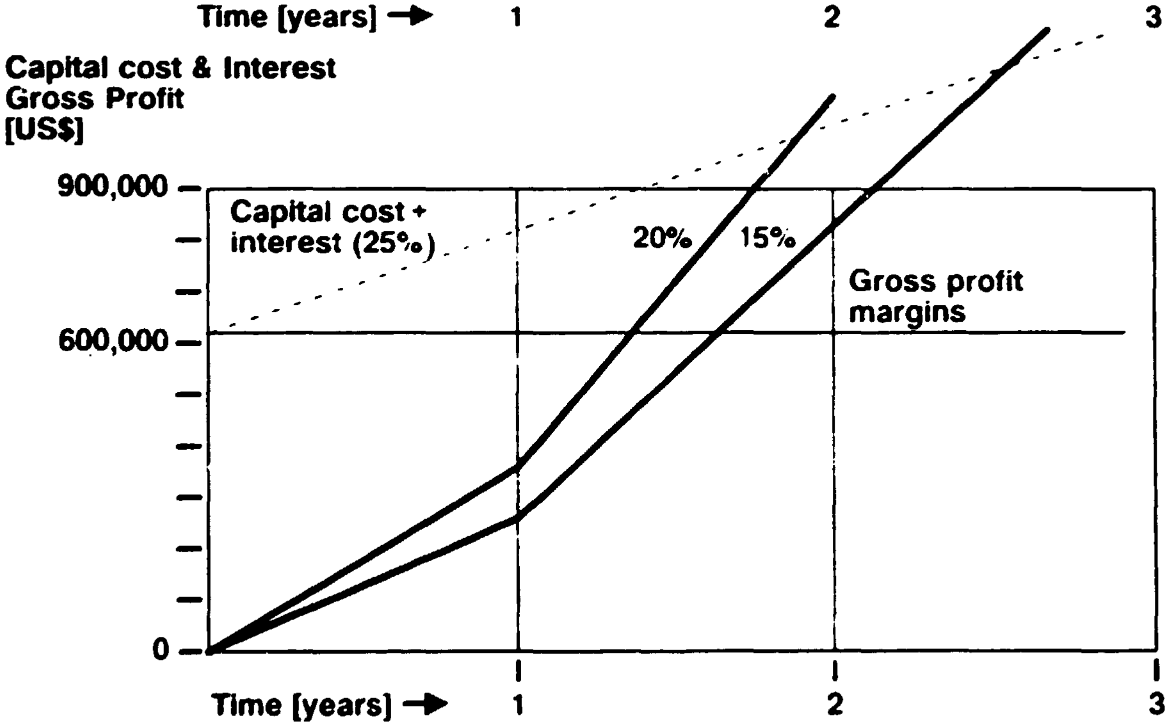
## 3. Estimation of Pay-Back Period:

**(as a function of different profit margins)**

**Assumption:**
- **specific operation costs remain unchanged (worst case)**
- **price of finished products: 750 US$/t**
- **capital interest rate 25%**

**The respective pay-back period will be determined by the assumed gross profit margin (15, 20%), taking only the output generated as "production increase" into consideration.**



# CHAPTER 5

# REFRACTORIES

## 5.1 INTRODUCTION

Over the last ten years there have been significant improvements in the quality of materials used. Together with better operational practices, these have led to a marked reduction in refractory consumption. The raw materials most frequently used as electric steelmaking refractories are magnesia carbon and doloma carbon. With the introduction of magnesia carbon refractories containing natural flake graphite into Europe in the late 1970s and early 1980s, the relatively low density, small crystal size magnesia traditionally used in pitch bonded and fired direct bonded bricks, required further improvements related to increasing the magnesia grain bulk density and the magnesia crystal size, while modifying chemical composition. Current efforts are concentrated on increasing the periclase (MgO) crystal size of synthetic magnesia to above 150 $\mu$m to improve the slag erosion resistance. Natural flake graphite has been utilised in a finer flake form due to improved manufacturing techniques.

Binder systems based on pitches and the phenol formaldehyde resin system continue to evolve. Modified resins have allowed the successful development of carbon bonded doloma products, which have given improved thermal shock and abrasion resistant properties over fired ceramically bonded doloma brick. Health and safety legislation currently being introduced will dictate binder system developments through the 1990s. [1]

## 5.2 REFRACTORY LININES FOR ELECTRIC ARC FURNACES

There has been a downward trend in refractory consumption over the past few years (Figure 5.1). As is evident, a considerable improvement has been achieved in refractory costs, despite a significant rise in installed electrical power. The consumption figures for sidewall and roof bricks, gunning material, and dolomite and magnesite masses are already so low that no further significant improvements can be expected in the near future. Consumption of sidewall bricks is currently 0.1 kg/t, roof bricks 0.15 kg/t, gunning material 0.5 kg/t and dolomite and magnesite 5 kg/t.[2]

The reduction of refractory consumption in EAF has been effected by plant/process development and refractory quality improvements as indicated in Tables 5.1, 5.2 and 5.3

Table 5.1: Effect of plant developments in the EAF on refractory consumption

| Plant developments | Benefits on refractory consumption |
|---|---|
| Major extension of steel side panels | Substitution of refractories and less refractories employed |
| Roof panels | Substitution of refractories and less refractories employed |
| Copper panels at slag line | Substitution of refractories and refractory cooling |
| EBT, slide gate system (new hearth, side profile) | Major extension of panels and reduced furnace tiling |
| Electrode spray cooling | Refractory roof cooling |
| DC furnace | No arc flame |

Table 5.2: Effect of process developments in the EAF on refractory consumption

| Process developments | Benefits on refractory consumption |
|---|---|
| Slag foaming practice | Protection from arc radiation |
| Secondary refining | Reduced tap to tap time |
| Scrap preheating | Reduced tap to tap time |
| Oxy-fuel burners | Reduced tap to tap time |
| Larger amount of oxygen injected | Reduced tap to tap time |

Table 5.3: Refractory improvements

| | Slag zone | Hot spot (slag zone) |
|---|---|---|
| 1980s | MgO + C fired, pitch impregnated | MgO + C fired, impregnated + fused MgO |
| 1990s | MgO + C pitch bonded + fused MgO + antioxidants (Si, Al) | MgO + C resin bonded + fused MgO + antioxidants (Si, Al) |
| Benefits | High residual C content<br><br>Better resistance to slag attack<br>Greater resistance to C reduction | High residual C content + better resistance towards thermal stresses |

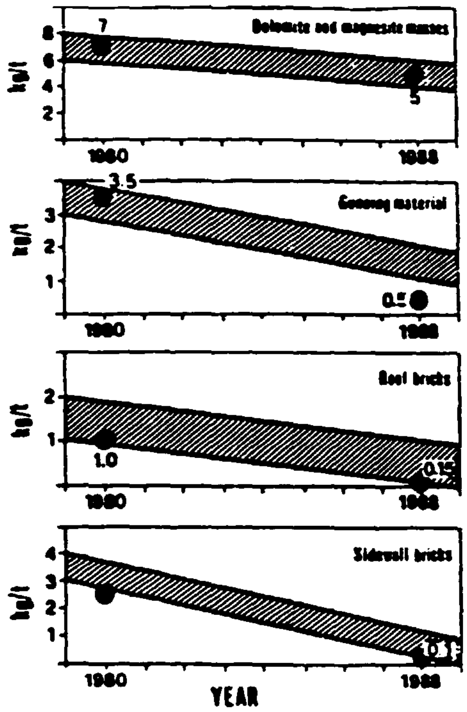



Figure 5.1: Improvement in EAF refractory consumption

During the last ten years the application of water cooled panels for the roof and walls of the electric arc furnace has spread rapidly. For this reason this update will not deal with the refractory lining techniques for fully refractory lined furnaces.

The practice of eccentric bottom tapping (EBT) is now widely adopted. Higher quality refractory materials have come to be employed for this purpose recently though other tapping systems, such as the slide gate type, are now being tried.

At the same time there have been changes in the internal profile of the EAF, an example of this being given in Figure 5.2.

### 5.2.1 Hearth area

Several chemical, thermal and mechanical factors act continuously on the hearth, i.e. corrosion, steel and slag infiltration, level and fluctuation of temperature, erosion and scrap impact. So far, the materials most commonly used for the working hearth continue to be dolomite and magnesite in the form of monoliths or bricks.

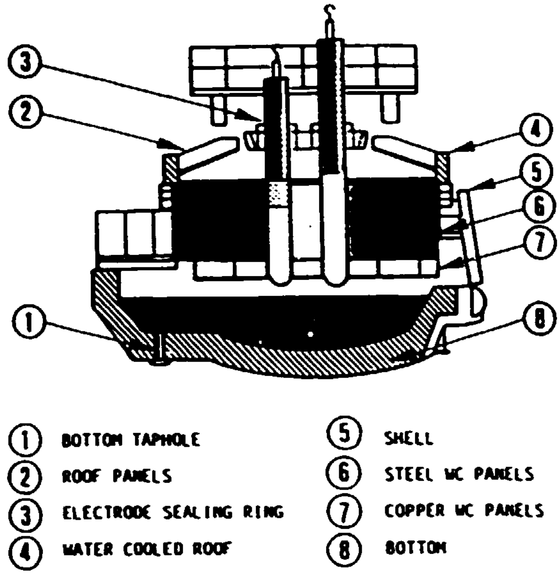



Figure 5.2: The internal profile of an EAF

In Japan and the USA, magnesite hearths are still the most frequently employed. In Europe the use of magnesite rather than dolomite is on the increase. In particular, the last layer generally consists of a magnesite ramming mix which is much simpler and faster to install than bricks.

To reduce costs the hearth area can be constructed in two layers [3] (Figure 5.3) where the sole casing is lined with two layers of magnesite bricks for safety, topped by a layer of dolomite bricks and rammed with a layer of magnesite mass. The tapping area is equipped with a perforated brick which encloses the cylindrical tapping bricks.

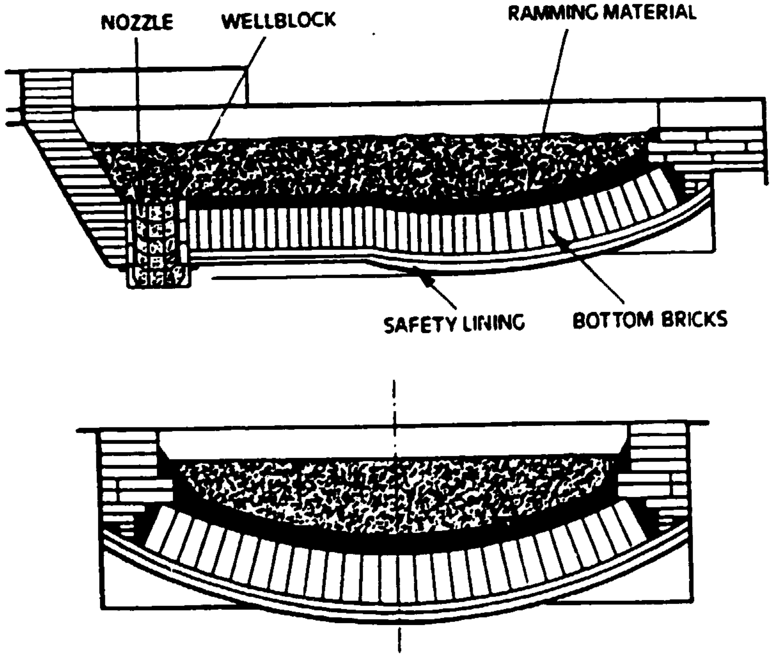



Figure 5.3: Cross section of a hearth area showing the two layers

Hearth repairs are made either with masses of the same kind or with special hearth repair mixes. To achieve a satisfactory life, the repair layer should be at least 150 mm thick. Repairs are possible in hot and cold furnaces alike, but it goes without saying that prior to repair the hearth has to be cleaned thoroughly.[4]

5.2.1.1 *Taphole systems*

The EBT system has found increased application in recent years. However, some recent applications of a taphole slide gate system are also giving good results.

*EBT system*

Adoption of this system has necessitated re-definition of the internal profile of the bottom and also the arrangement of panels, hence of the refractories within the EAF. Figure 5.4 illustrates a section and a plan of modern furnaces,[5] more precisely a 155 t EAF. Table 5.4 indicates the refractories utilised in the various parts by some constructors.

Table 5.4: Refractories used in different parts of a modern furnace

| Position | $SiO_2$ % | $Al_2O_3$ % | $Fe_2O_3$ % | CaO % | MgO % | Retained carbon % |
|---|---|---|---|---|---|---|
| X | | | | | 82 | 14.5 |
| Y | 0.1 | 0.04 | 0.12 | 0.52 | 29.13 | |
| Z | 0.8 | 0.4 | 0.4 | 2.3 | 95 | |
| U | 5.5 | 0.7 | 0.7 | 1.3 | 90 | |
| V | 1.4 | 0.5 | 0.5 | 4.9 | 92.7 | |
| X | | | | | 72.4 | 24.5 |
| Y | | | | | 83.1 | 11 7 |
| M | 0.7 | 0.5 | 3.5 | 18 | 77 | |
| R | | | | | 89 | 20 |
| B | | | | | 89 | 20 |
| A | 1 | 0.3 | 0.3 | 2 | 96 | |
| P | | 0.5 | 0.2 | 1.2 | 96.5 | |

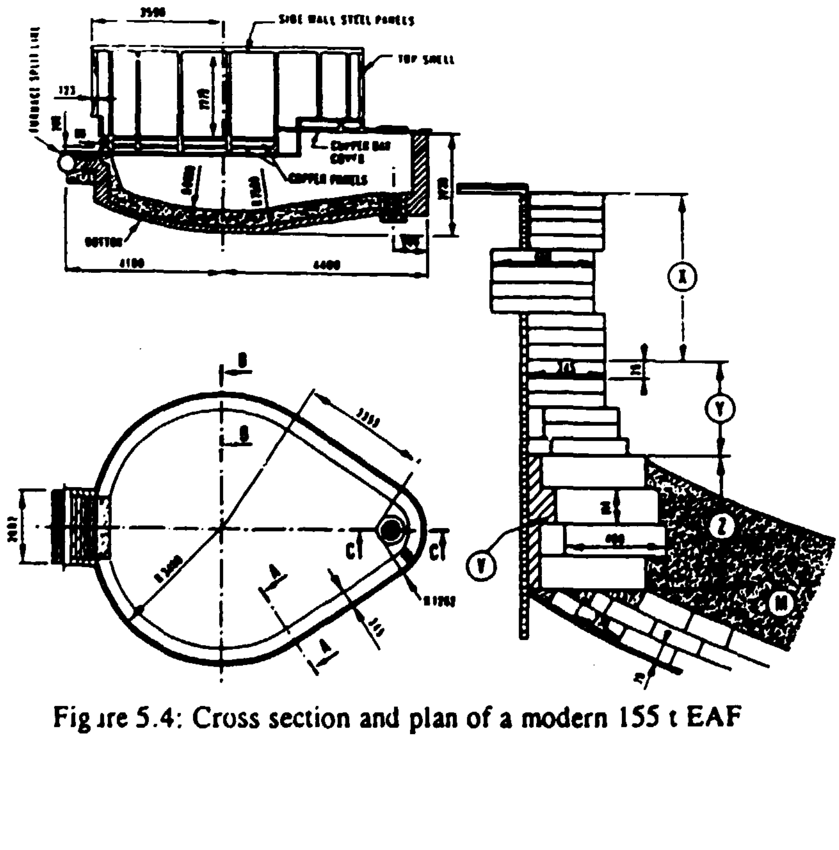


Figure 5.4: Cross section and plan of a modern 155 t EAF

The lower slope of the EAF necessary for tapping (less than 10°) compared with conventional furnaces (35°) has permitted extension of the panelled zones to cover some 90% of the side walls, it has also allowed reduction in the distance between the slag line and panels by installing copper panels (for safety reasons) to replace some of the refractory.

In order to reduce heat losses in the lower part of some plants, shorter magnesite carbon bricks (15% carbon) have been built in front of the copper panels (Figure 5.5).

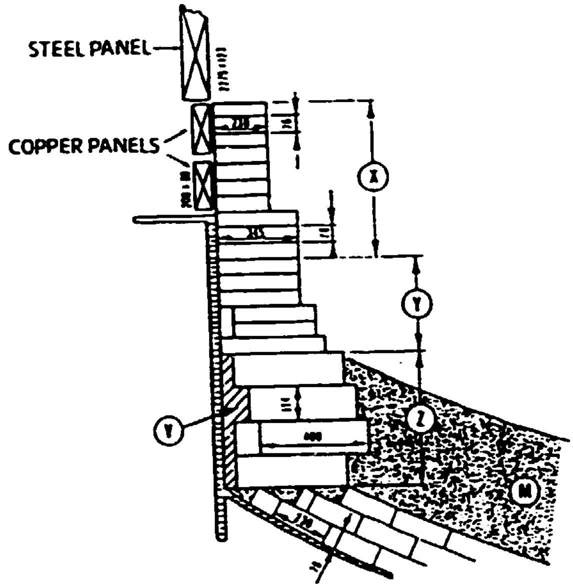



Figure 5.5: Cross section of an EAF hearth showing use of shorter magnesite carbon bricks (see Table 5.4 for material code)

Figure 5.6 illustrates a typical EBT layout in a 155 t EAF, together with the materials employed. [5 6 7 8 9] The surrounding rings are a fired, pitch impregnated special quality magnesite made from low iron sinter magnesia. In most cases, the life of the surrounding rings is identical with the hearth life, so that they only need changing when the complete lining is renewed.

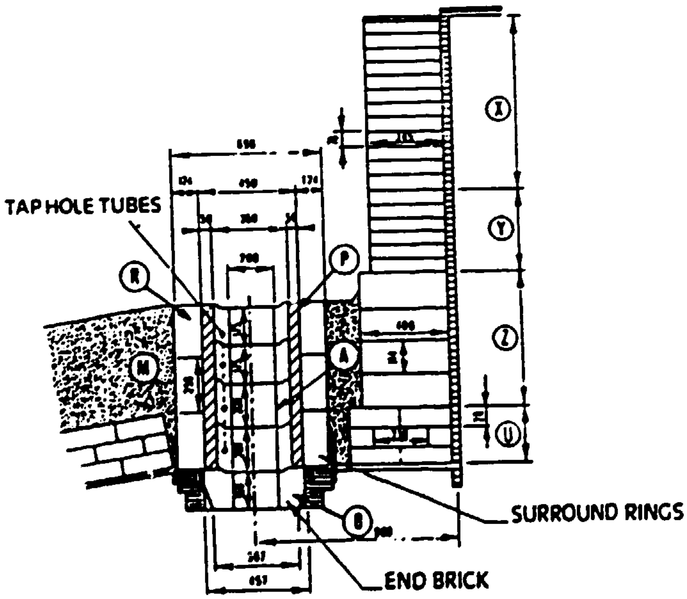



Figure 5.6: Typical EBT layout of a 155 t EAF (see Table 5.4 for material code)

Taphole tubes have an average life of 150 to 250 heats, depending to a large extent on the refractory material chosen. Very good thermal shock resistance and sufficient erosion resistance at high temperatures are required for achieving satisfactory lifetimes. Due to their high structural flexibility, synthetic resin bonded MgO-C qualities have given good results. Their residual carbon content is between 14 and 20%.[4] Taphole tubes are laid absolutely dry, without mortar.

The end brick must also be highly resistant to mechanical damage, which can be caused during clearing. The danger of decarbonisation is also particularly great during cleaning. Depending on operating conditions, end bricks have a life of between 90 and 160 heats.

A quality of refractory that has provided very good results recently is synthetic resin bonded MgO-C brick containing antioxidants. These are characterised not only by good structural flexibility but also by very high structural strength and oxidation resistance with a residual carbon content of around 14%.[4]

A plugging compound mixture of $MgO\text{-}SiO_2$ with 10% $Fe_2O_3$, grain size 0.5 to 0.6 mm is generally used to fill the taphole at the end of the heat.

*Taphole slide gate*

A new system has been developed recently. This involves a taphole slide gate set up in place of the spout on the furnace shell.[10, 11] An example of an application on a 100 t furnace[10] is given in Figure 5.7. The installation utilises a fixing flange on the external channel.

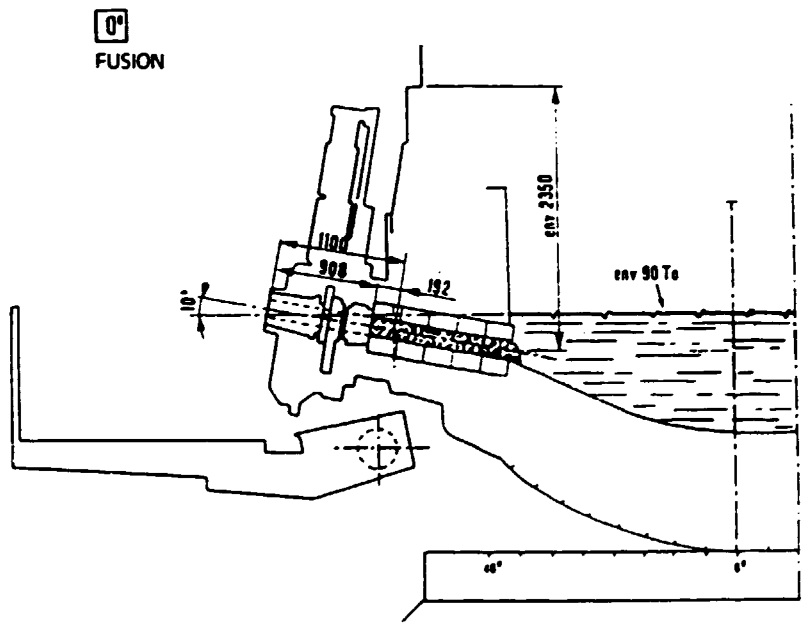



Figure 5.7: Taphole slide gate installed on a 100 t furnace

The centreline of the internal refractory channel slopes 10° to the horizontal. It is closed by means of lime chippings. Zirconium inserts are used to increase the life of the outlet nozzles.

The great advantage of this closure system is that it allows almost complete retention of the slag in the EAF, permitting not more than 200 kg to pass into the ladle. The average life of the refractory channel is about 68 heats, while that of the box nozzle is about 28.

**Annex 2**

# TIME AND TIDE WAIT FOR NO MAN

## VAIS human resource and organizational development

The success of a company is no longer simply the result of better equipment and processes. Employees now represent the key factor in strategic success (Fig. 1). Both as individuals and as part of an integrated and harmonious team. It is the human element that unifies materials, machines and methods to create organizational and thechnological success. VAIS human resource consultancy is based on the recognition of this fact (Fig. 1a).

Company efficiency and productivity are endangered by problems as diverse as the wastage of experienced staff, a lack of employee motivation and the failure to exploit staff potential (Fig. 2). Furthermore, market-related and technological developments have become increasingly short-term. In other words, the tempo of global industrial evolution makes both company and personal development essential.

## Diagramm

Converting the challenge of competition into constant company improvement (Fig. 3).

Those that do not advance will simply fall behind. Fitness for competition can only be secured by constant improvement.

VAIS HRD (Human Resource Development) and OD (Organizational Development) confront these dilemmas head on and like all company consulting are practice and implementation oriented.

VAIS programmes aim to instill efficiency and maintain the knowledge, skills and teamwork needed for company success and to ensure that each individual and the company as a whole (Fig. 4):

| | |
|---|---|
| KNOWS WHAT TO DO | through fast and effective information systems |
| AND HOW TO DO IT | due to training and on-going education |
| CAN DO IT | thanks to competent leadership, organizational flexibility and suitable equipment |
| AND IS WILLING TO DO IT | as a result of motivation and humane working conditions |

# THE VERY LATEST METHODS FOR IMPROVED PERFORMANCE

The systematic approach to HRD questions can again be divided into three strategic phases. Firstly, analysis which involves an assessment of corporate culture, values, habits, rules and procedures and the detection of interface problems between business units. Secondly, a design phase that involves the development of HRD systems for individuals or complete organizational units. And thirdly implementation, incorporating the putting of the HRD systems and instruments into practice. All three phases involve an optimized combination of instruments that have been profen (Fig. 5).

### The method employed invoice (Fig. 6):

* Basic and further training
* Group working for the planning of strategic goals and individual measures fo personal and organizational development.
* Assistance in implementing these measures and monitoring their progress
* The continual scrutiny of the most important operational and performance parameters
* The analysis of company strenghts and weaknesses to allow the focusing of the HRD and OD programmes

# THE ROLE OF THE VAIS CONSULTANT AS AN AGENT FOR CHANGE (Fig. 7)

| | |
|---|---|
| Launcher | - using a methodical/systematic approach |
| Promoter/Accelerator | - concentrating on development objectives without day-to-day business |
| Tutor/Expert | - providing special training activities |
| Auditor/Evaluator | - making assessments from a neutral and critical viewpoint |
| Referee/Benchmark | - comparing personnel performance with quality standards |

# COMPETITIVE ADVANTAGE

**lies not in the superior skills of individuals . . .**

**but also in the superior teamwork under supportive leadership**

Fig. 1

Fig 1a

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# MATERIAL MACHINE & METHOD

**do not comprise a successful technology until the human factor is added.**

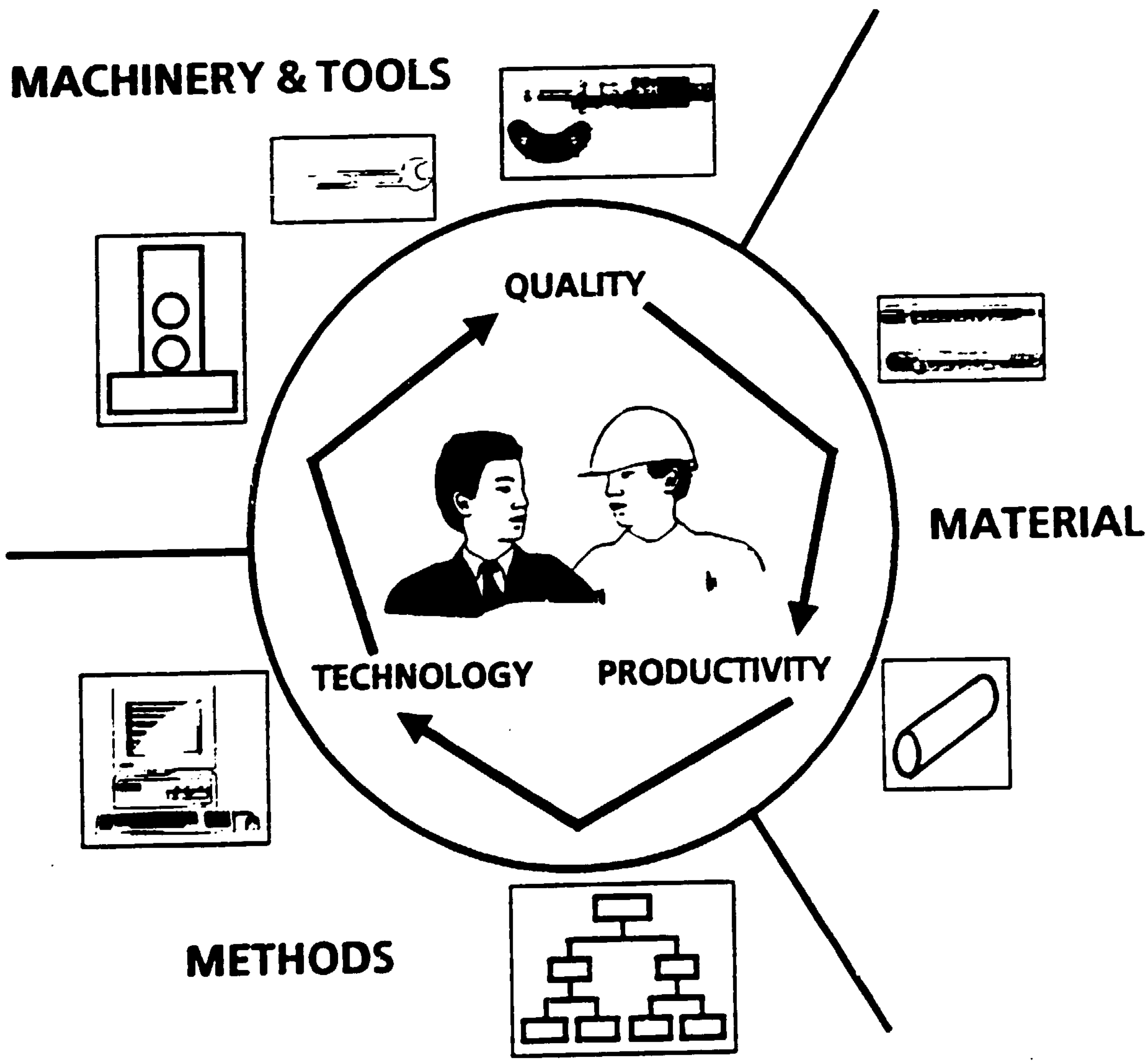

Fig 2

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# WHAT CONSTANTLY ENDANGERS THE EFFICIENCY OF AN INDUSTRIAL PLANT?

- Loss of Key Personnel
- Inadequately Qualified Entrants
- Promotion of Personnel to unfamiliar positions
- Decrease in Motivation
- Diminishing Knowledge/Skills due to underutilization
- Technological Developments (introduced by competitors)
- Unfavorable Changes in the Economic Environment
  - Raw Material/Energy Cost
  - Product Prices
  - Market Demand for higher Product Quality
- Wear of Plant Equipment

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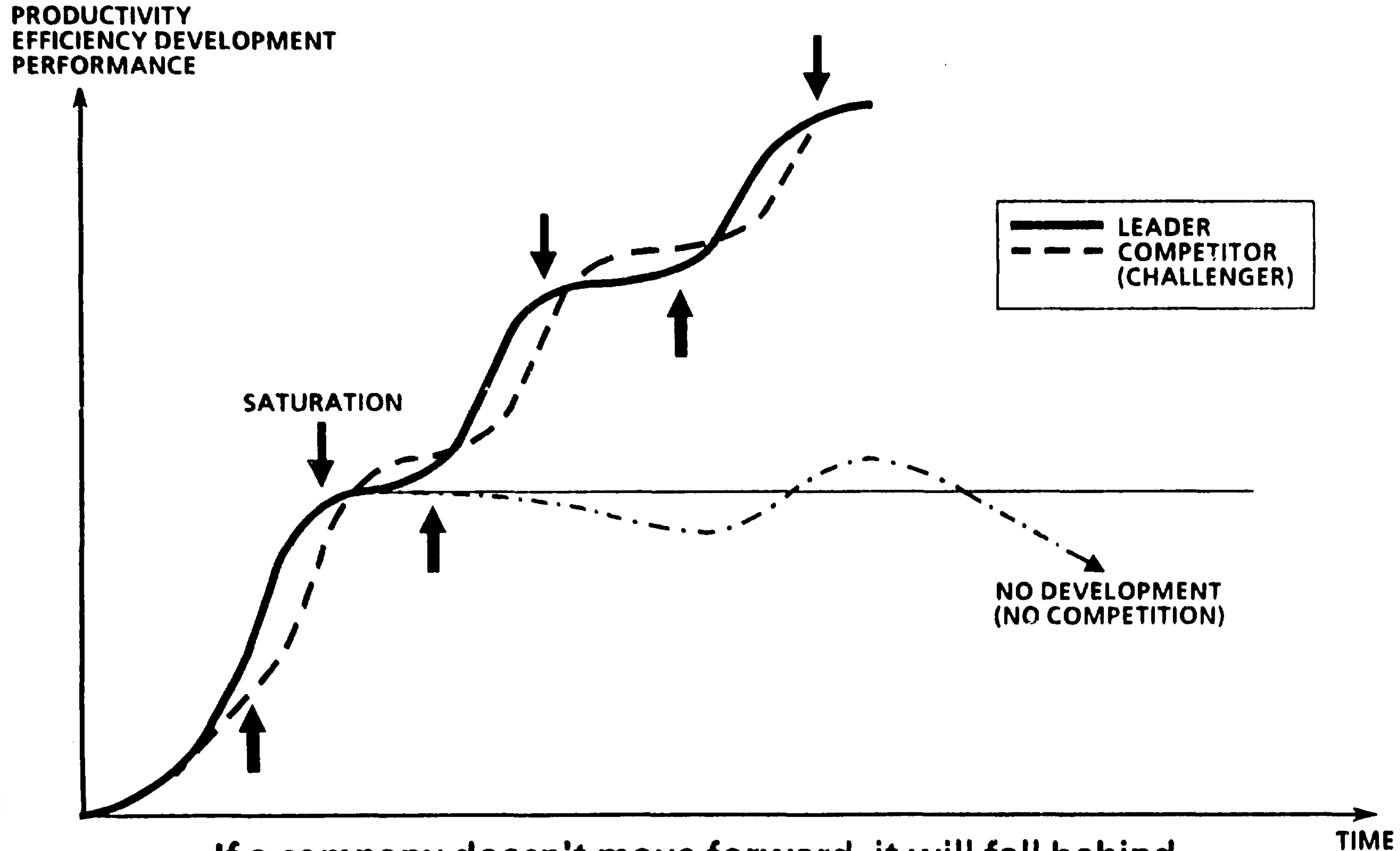
# FITNESS FOR COMPETITION REQUIRES HRD & OD




**If a company doesn't move forward, it will fall behind.**

Fig. 3

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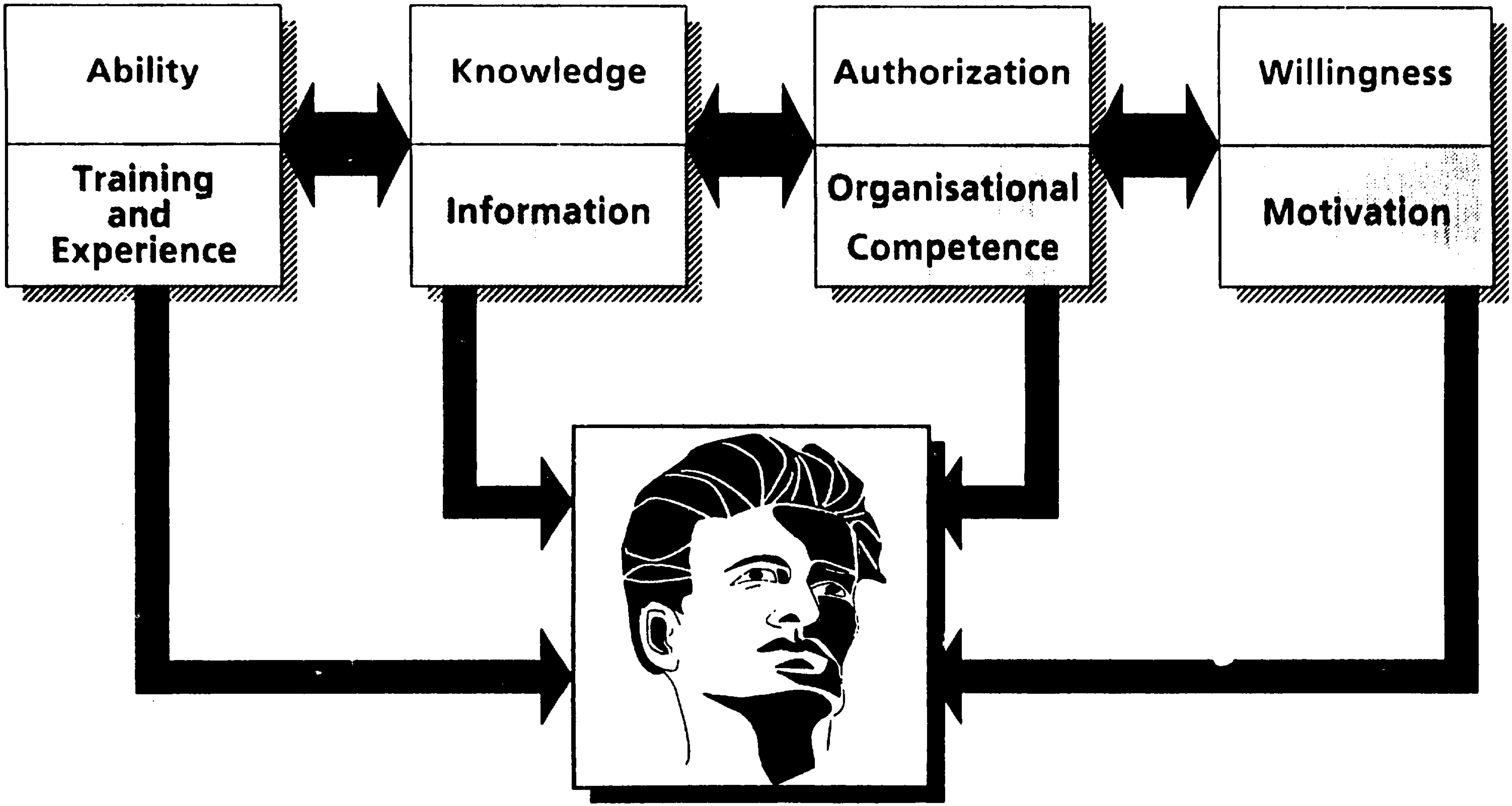
# GOALS OF HRD & OD




**EFFICIENCY OF HUMAN PERFORMANCE**

Fig 4

Fig 5

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# Systematic Approach to HRD & OD

**1. Analysis**

Company:

goals, culture, values,
habits,
rules & procedures

Organizational:

interface problems

**2. Design**

HRD systems

OD systems

**3. Implementation**

Putting systems and instruments into practice

# Methods of HRD & OD

- Basic and further training

- Group working > > > strategic goals, individual measures

- Guided implementation
  Continuous monitoring of progress

- Continual scrutiny of performance parameters

- Analysis of company strengths & weaknesses

Fig 7

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# The Role of the Consultant in HRD & OD Process

| | |
|---|---|
| LAUNCHER | by methodical / systematic approach |
| PROMOTER / ACCELERATOR | can concentrate on development objectives (no day to day business) |
| TUTOR / EXPERT | through special training activities |
| AUDITOR / EVALUATOR | from a neutral, critical position |
| UMPIRE / YARDSTICK | compares personnel performance with quality standards |