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

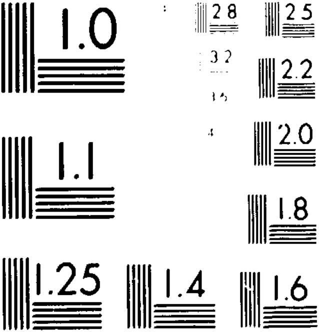
FAIR USE POLICY

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


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

C9747

Distr.
LIMITED

ID/WG.305/23
28 April 1980

ENGLISH
ORIGINAL: FRENCH

United Nations Industrial Development Organization

Seminar-Workshop on the Exchange of
Experiences and Technology Transfer
on Mini Hydro Electric Generation Units

Kathmandu, Nepal, 10-14 September 1979

MALI COUNTRY PAPER*

by

U P D E A**

* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been translated from an unedited original.

** Union of Producers, Conveyors and Distributors of Electric Power in African Countries, Madagascar and Mauritius.

80 38782

I. INTRODUCTION

Many different factors are of course decisive for the developing countries' industrial expansion, but none is more fundamental or urgent than the provision to them of abundant cheap energy.

Whether it be a question of modernizing agriculture, making soils usable by irrigation, processing or preserving agricultural products and commodities, extracting and processing raw materials, exploiting forestry resources, transporting manufactured goods or seeking to promote social welfare, electricity in all cases provides an immediate, flexible response to the development needs of countries undergoing rapid expansion. It is therefore unquestionably an indispensable element, if not the essential element in the economic revolution desired by all with a view to achieving a more harmonious world. Hence the need to implement a comprehensive electrification policy (rural electrification, electrification of individual homes and construction of major works) which meets the needs of modern industry. The areas in which electrification schemes are needed are generally scattered, far from the coast, widely separated, poorly served by transport and communication links, sparsely populated, economically depressed and lacking in skilled manpower and often present difficult climatic conditions.

These unfavourable conditions impose special constraints as regards both the design and the operation of production and distribution schemes. Since it is impossible for the time being to establish a general interconnexion network, a generation unit with its own independent distribution network must be built in each area.

These general factors apply in particular with respect to the Republic of Mali, a land-locked country with an area of 1,240,000 km^2 and a population of about 5.5 million.

The distribution of generation units throughout the country (see map) shows a predominance of thermal units and it could logically be asked why that should be so in a country where sun and hydraulic resources are far from lacking. Since we are not here concerned with new forms of energy, we shall simply point out that:

1. The harnessing of hydro-power calls for very substantial funds which developing countries find it difficult to obtain.

2. At the present stage of technological development, the price per kwh of new forms of energy (solar, geothermal, wind, etc.) does not appear competitive.

CASE OF A SOLAR POWER STATION AT TIMBUCTOO

Proposed capacity: 90 to 100 kw.

Operating 12h day, alternating with the thermal power station.

Total cost: 1,925 million Malian francs, written off over 20 years with an interest rate of 5 per cent per year, giving a price per kwh of about 450 Malian francs.

GENERATION UNITS	INSTALLED CAPACITY (kva)	AVAILABLE CAPACITY (kva)	ANNUAL PEAK, 1978 (kw)
BAMAKO (H + TH)	29,400	20,100	15,400 May
BOUGOUNI (TH)	225	225	85 April, November, December
F A N A (TH)	1,025	925	380 January
G A O (TH)	520	520	275 May - September
K A Y E S (H + TH)	1,790	1,200	938 December
K O U T I A L A (TH)	1,310	810	780 December
M O P T I (TH)	1,000	550	490 April
MARKALA (SEGOU) (TH)	2,162	1,090	930 September
SIKASSO (TH)	1,060	650	350 December
TIMBUCTOO (TH)	250	150	188 November

II. SOTUBA HYDRO-ELECTRIC POWER STATION

II.1 DEVELOPMENT OF PRODUCTION AT BAMAKO BEFORE THE INSTALLATION OF THE HYDRO-ELECTRIC POWER STATION AT SOTUBA

YEAR	1960	1961	1962	1963	1964
PRODUCTION (mwh)	12,080	13,240	16,420	18,930	22,120
PEAK CAPACITY (kw)	2,860	3,260	3,760	4,070	4,820

From 1955 to 1960, power production at BAMAKO was carried out by "ENERGIE A.O.F." and SAFELEC, which, when ENERGIE DU MALI (E.D.M.) was set up, left behind practically no usable documents.

These figures, reflecting an average annual growth of 15 per cent, indicate some vitality in energy consumption despite the mass departure of the European population, which, with its high purchasing power, helped to ensure a constant growth in the demand for energy.

II.2. THE SCHEME AT SOTUBA

II.2.1 BACKGROUND INFORMATION ON SOTUBA AND ITS CHARACTERISTICS

A study of the development of electric power production in the Bamako area reflected in the above table indicates the need for energy expansion. Nevertheless, although the construction of this plant was considered as far back as 1927, its main features were not realized until 1960. The civil engineering work, started on 19 February 1964, was expedited in order that the electro-mechanical installation work could start in September 1965.

The tailrace was submerged at the end of June 1965. The water intake and delivery structures were submerged on 1 February 1966. The first unit started operating on 19 March 1966 and began to feed power into the network on 2 April of that year.

The power station was inaugurated on 16 December 1966.

GENERAL CHARACTERISTICS

Forebay	117,000 km^2
Average annual discharge	1,545 m^3/s^3
Average annual high water flow	6,200 m^3/s
Exceptional high water flow	11,000 m^3/s
Average low water flow	48 m^3/s
Utilizable discharge	120 m^3/s
Head.......................................	3.50 to 7.40 m
Power ex-plant	5,200 kw
Producibility	37.7 gwh

PLANT

2 KAPLAN TURBINES:

Discharge	60 m^3/s
Power	2,850 kw
N = ...	100 rpm

2 ALTERNATORS:

Power	3,400 kva
Voltage	2 kv
PD^2 = ...	2,400 TXm^2

2 TRANSFORMERS

Power	3,400 kva
Voltage	2/31 kv
Electric cable, SOTUBA - BAMAKO	
Voltage	30 kv
Overhead electric cable	7.7 km
Underground electric cable	4.2 km

BAMAKO STATION

2 TRANSFORMERS

Power	3,200 kva
Voltage	31/16.5 kv

Fluctuations in the utilizable discharge are shown on the curve:

(1) /See curve, graph SOU - 99637

(2) Net head

(3) Momentary power available at SOTUBA limited to 5,000 kw. As can be seen in the graph, this power is the product of discharge x net head x total productivity coefficient of plant. The area it encloses gives, by integration, the theoretical annual producibility, which amounts to 37.7 gwh.

III. STATISTICS FOR PRODUCTION FROM SOTUBA

III.1 TABLE SHOWING PRODUCTION BY THE BAMAKO UNIT

MONTH	1975		1976		1977		1978	
	DARSALAM	SOTUBA	DARSALAM	SOTUBA	DARSALAM	SOTUBA	DARSALAM	SOTUBA
January	693,700	3,674,000	964,400	3,810,000	1,618,400	3,922,000	2,925,900	3,479,000
February	1,687,500	2,882,000	1,397,100	3,438,000	1,837,800	3,732,000	3,858,700	2,646,000
March	4,334,500	1,357,000	3,950,200	2,191,000	3,196,500	4,493,000	5,958,000	1,672,000
April	4,912,100	1,326,000	5,324,300	1,174,000	5,196,500	1,731,000	5,832,000	2,068,000
May	3,255,600	3,358,000	6,935,900	2,077,000	4,915,500	1,986,000	5,486,900	2,968,400
June	1,782,800	3,760,000	6,045,700	3,629,000	3,140,000	3,688,000	4,339,400	2,726,000
July	1,605,900	3,277,000	2,054,000	3,640,000	2,708,500	3,671,000	3,547,900	2,992,000
August	2,183,900	2,567,000	2,878,500	2,373,000	2,956,300	3,039,000	3,465,400	2,841,000
September	2,663,900	1,990,000	3,131,200	2,388,000	3,407,700	2,208,000	4,128,100	2,060,000
October	3,359,100	2,186,000	3,704,600	2,246,000	3,691,700	2,989,000	5,126,700	2,348,000
November	1,695,100	3,249,000	2,734,100	3,528,000	2,410,500	3,530,000	3,722,600	3,044,000
December	991,500	4,096,000	1,184,000	3,507,000	2,286,700	3,733,000	2,530,300	4,076,000
TOTAL	29,165,500	37,220,000	35,126,400	33,001,000	37,366,100	37,662,000	50,921,800	32,920,000

III.2 ANALYSIS OF LOAD SHARING

With a total production of 397,003,000 kwh, the two units have been operating for 104,225 hours (unit 1) and 106,451 hours, respectively, as of 30 July 1979.

A study of the preceding table indicates that:

1. In 1975 and 1977, production almost reached the theoretical producibility. This should not be too disturbing if we remember that the producibility calculated took into account several essentially variable parameters (divertable flow, discharge of the race, etc.).

2. Despite the years of drought, SOTUBA's output during the period under review accounts for roughly 50 per cent of the power drawn by Bamako and the surrounding area. This is therefore a substantial saving for our young economy, which is gravely affected by the constant rises in the prices of petroleum products. In this context, it is easy to understand the efforts made to complete this work, investments in respect of which were distributed, as at 17 June 1965, as follows:

	Malian francs
CCCE (Caisse centrale de coopération economique - France)	1,378,974,000
FAC (Fund of Aid and Co-operation)	1,258,891,813
Republic of Mali	960,711,784

with an agreed overrun of 78,438,071 Malian francs.

IV. SOTUBA AFTER THE REGULATION OF THE NIGER BY THE SELINGUE DAM

During the period of medium waterflow - from 1 December to 15 March and from 15 May to 15 July - the natural flow enables the SOTUBA plant to operate at full capacity. For this purpose, we raise the height of the dam with plastic bags full of sand, which are watched from 15 May to 15 July. This practice has enabled us to obtain the maximum power of 5Mw in an average year.

RECAPITULATION OF MAXIMUM POWER AT THE PRESENT STAGE

(without regulation of the Niger)

Month	Power (kw)
January	5,000
February	5,000
March	5,000
April	5,000
May	5,000
June	5,000
July	4,400
August	3,800
September	3,100
October	4,400
November	4,800
December	5,000

We have seen that, under present conditions, the producibility of SOTUBA is 37.7 gwh, with the minimum for a month occurring in April (about 1.7 gwh).

The United Nations feasibility study of February 1973 concerning the double plant envisages a producibility increased to 76 gwh. According to the same source, the minimum for a month would be 38 gwh and would occur in September, barring any mechanical breakdowns.

However, still according to the same study, which, moreover, foresees a substantial gradual strengthening of the DAR-SALAM thermal power station, the SOTUBA extension will be operational only in June 1988; hence the need for us to service the equipment properly in order to ensure optimum exploitation.

V. INCIDENTS AND REPAIRS

V.1 HEIGHTENING OF THE AIGRETTES DAM

The provisional heightening operation using sandbags carried out each year at low water brings about a considerable improvement in producibility.

V.2 AT SOTUBA

V.2.1 UNIT No. 1

The main difficulty in this unit consisted in serious problems for an output of around 800 kw (the critical stage of assumption of load). This phenomenon was encountered repeatedly in 1978. Several hypotheses were evolved:

(a) a defect in the oil distribution column of the Kaplan head;

(b) sticking owing to slight friction on some part of the runner-command pilot slide valve piston;

(c) a sticking point in the runner blade command distribution mechanism (lack of oil due to leaks at the joints of the blades);

(d) poor operation of the safety valve of the cone;

(e) Electrical cut-out of the electromagnetic speed regulator at some stage of assumption of load.

By process of elimination, we have been able to detect a number of failures, namely:

- In the sleeve flange (part B on plan RIVA 2.854.770) owing to deterioration of the threads and exposure of the straight pins (part E on the same plan).
- In the ring joint, R 124 - 4, which caused a short-circuit in the runner, and the discharge circuit and oil loss.

PROBABLE CAUSES

Frequent, violent strain on the machines due to the sudden demands of the network.

The repair was carried out in the workshops of SOMATRA at Bamako while the arrival of the part which had been ordered (complete oil distribution column) was awaited.

V.2.2 UNIT NO. 2

We noted traces of friction on the servo-motor piston (2mm in depth and varying from 4 to 5 mm in length), probably due to the infiltration of dust during the final stages of construction work. This caused serious oil leaks (consumption has recently increased by some 90 per cent) which steadily worsened despite filling with Araldite. The work on the servo-motor planned for 15 March to 15 April 1979 has been deferred until the same period next year for operational reasons (good hydraulic conditions and important units of the DAR SALAM thermal power station immobilized owing to lack of spare parts).

The spare parts to be used for this work, which were sent from Europe with allowance for machining, will be machined on the spot by the Malian National Railways (KOROFINA workshops), SOMATRA or the MARKALA SMB.

V.3 AT FELOU

V.3.1 CHARACTERISTICS

Dam:	fixed type
Plant:	low heads with forebay and natural current
Gate:	fixed roller type
Turbine:	FRANCIS fixed blade

Constructor:	Société générale de constructions électriques et électromécaniques Alsthom Atlantique
Power:	750 hp at 300 rpm
Head:	13.41 to 8.50 m
Speed regulator:	model CEF 75

V.3.2 WORK PERFORMED

There is no trace in the files of the work performed between 1953 and 1963 (improvement of the unit's bearing cooling system). That performed in 1977 (REPELEC) and 1979 (the latter performed by us on the exciter and speed regulator have definitely improved the operation of the FELOU unit.

VI. GENERAL CONCLUSIONS

The SOTUBA Hydroelectric Power Station, of which we have tried to give you some idea, just falls within the scope of the traditional definition of a micro generation unit (production plant with a capacity of from a few dozen to 1,000 to 2,000 kw and in exceptional cases from 5,000 to 10,000 kw depending on design; head ranging from 2 metres to several hundred metres, rate of flow ranging from several dozen l/s for high heads to several dozen m^3/s for low heads). These plants are usually simple in design, rugged, with local utilization of the energy produced. In this context, we see that the FELOU hydro-electric generation unit at Kayes better fulfils the definition criteria for a micro generation unit. However, we have very few documents on this production unit, which dates back to 1925, and the data we have been able to reconstitute are as yet incomplete, hence the interest we have shown in SOTUBA in our endeavour to contribute to this Seminar.

Bamako, 2 September 1979.

** VCC **

ENERGIE DU MALI

GENERAL DIRECTORATE

BAMAKO

REPUBLIC OF MALI

ONE PEOPLE - ONE GOAL - ONE FAITH

ANNEX

Various hydro-electric generation unit projects in Mali or in the subregion.

PLACE	CAPACITY (Mw)	ANNUAL PRODUCTION (Gwh)
MANANTALI	200	800
PETIT KENIE	20	100
GRAND KENIE	120	600
GALOUGO	285	1,640
GOUINA	100	570
FELOU	75	430
GOURBASSI	20	111
DIOILA	20	120
BALANDOUGOU	7	40
TOSSAYE	18	67.2
LABEZANGA	14	67

HARNESSING OF THE KENIE RAPIDS

(1) SITE: 35 km downstream from Bamako and 3 km from the Tienfala Gou - accessible by a road which is to be built (7 km).

(2) CHARACTERISTICS:

As regards the Niger River, there are two clear-cut periods:

August to November: high water

January to June: low water

Rate of flow at low water: 20 to 150 m^3/s, averaging to 35 to 40 m^3/s;

Rate of flow at high water: 4,500 to 11,000 m^3/s, averaging to 6,000 m^3/s.

PETIT KENIE

These projections do not take into account the regulating effect of the future SELINGUE dam.

- Proposed installed capacity: .... 20 Mw
- Annual producibility: .... 100 gwh
- Guaranteed capacity at low water: .... 2,600 kw
- Guaranteed capacity at high water .... 8,800 kw

The upstream regulation by the SELINGUE dam, beginning in 1981 will (if the project is executed) enable the guaranteed capacity to be increased to 14,000 kw. In this case, the installation of a potential of 4 x 10 Mw would be proposed with:

- Usable gross head: 9 to 13 m;
- Guaranteed capacity (for the regularized flow of 220 m^3/s at high water): 23 Mw;
- Producibility under the guaranteed capacity: 200 gwh year;
- Total producibility in an average year for an installed capacity of 40 Mw: 315 gwh year.

GRAND KENIE

- Maximum installed capacity: 120 Mw;
- Producibility: 600 gwh year for a rate of flow regularized at least at 200 m^3/s.

CONSTRUCTION OF SMALL DAMS IN THE DOGON PLATEAU

1. Dams in existence before the five-year plan

- 1952-1960	15
- 1960-1971	2
- 1972-1974	13
Total	30

2. Construction of dams during the five-year plan

2.1 Planned 45

2.2 Actually constructed 15

2.3 Sources of financing

FRG	1,678	million Malian francs
CIMADE	58	million Malian francs
IBRD	67	million Malian francs
Total	1,803	million Malian francs

The financing has been used for:

- The construction of new dams (15);
- Repair of some existing dams;
- Provision of equipment and construction materials:
- Sanitation work.

2.4 Total number of dams constructed: 30 + 15 = 45 since 1952

3. Problems connected with the operation of the dams

Of the existing dams (45), 22 to 23 are operating.

Reasons: **Masonry faults:**

Faulty prospecting of sites;

Inadequate technical resources.

4. Prospects for implementation

4.1 In the immediate future

- a request has been sent to FAC for the construction of three dams in 1980 (the studies have already been financed by a Belgian company);

- The construction of three other dams is under way, financed by CIMADE; probable completion: 1979;
- Repair of a dam by FAC in the near future;
- Starting in 1980, the construction of dams will be an integrated operation (dam + well-drilling + human health component).

4.2 In the longer term: 61 dams will be either repaired or constructed.

5. Economic Aspects

- Irrigated area/dam = 4 hectares;
- Production: 20 to 25 tonnes of onions per year with the possibility of producing two crops a year;
- Unit cost per dam: about 79 million Malian francs.

FACILITIES OF THE VARIOUS LOCAL WORKSHOPS

I. SOMATRA

DESCRIPTION	CAPACITY
LATHES I	Length of work-piece, 1,250 mm. Distance between centres, 180 mm.
II	Length of work-piece, 1,000 mm. Distance between centres, 300 mm.
III	Length of work-piece, 3,000 mm. Distance between centres, 300 mm.
IV	Length of work-piece, 3,000 mm. Distance between centres, 350 mm.

DESCRIPTION	CAPACITY
Grinding machine	Length - 2,000 mm. Distance between centres - 250 mm.
Milling machine	Universal
Boring machine	Ø 120 mm.
Injection	8 cylinders. Maximum output - 160 cm^3
Grinding	of seats and valves
Press	3 tonnes
Injection	- Complete renovation of the injection pump - Testing and adjustment of the flow of pumps of from 1 to 16 cylinders - Adjustment of corner clamping - All work on injectors

II. EMAF (ENTREPRISE MALIENNE DE FONDERIE)

FOUNDRY	Making of moulds and casting of aluminium, cast iron and bronze parts
MACHINING	Rough machining of sprue, etc. Turning of ordinary parts on a small-capacity lathe Expansion under way

BRIEF LIST OF THE MAIN MACHINE TOOLS IN THE MARKALA WORKSHOPS AND THEIR APPROXIMATE POWER

Furniture workshop: Makes metal furniture out of very thin sheet metal, boats, boiler-making products etc.

Facilities: One compressor, 7.5 kw

One Bombled bender, 9.5 kw

One guillotine shearing machine, 10 kw

Framework workshop: Specialized in the manufacture of all kinds of metal structures, non-mechanized agricultural equipment, pipes and tubes and simple boiler-making products.

One electric forge 10 kw

One guillotine shearing machine, 15 kw

One rolling machine, 4 kw

A 7 kw cutting-off machine

One power hammer 10 kw

Central mechanical workshop: Manufactures and repairs machine parts according to a diagram or model. It should be noted that many factories in the country, including SOMASAC, SOCIMA, the KOULIKORO Oil Mill and the MARKALA electric power station, to name only a few, owe their continuity of operation to the many repairs carried out on their equipment.

One shaping machine .... 8 kw
One horizontal lathe, 53 .... 53 kw
One radial milling machine .... 7.5 kw
One radial drilling machine .... 7 kw
One radial grinding machine .... 11.8 kw
One radial slotting machine .... 8 kw

Wood or model-preparation: Its main activity consists in the making of wooden models of all parts. At the same time, it makes luxury furnishings.

A central compressor which, although it is of no use to the wood workshop, provides the compressed air required for the painting operations of the other workshops and for cleaning castings, power - 50 kw.

Electricity workshop: Mainly responsible for attending to installation work and breakdowns in all the electric circuits and motors, both in the workshops and outside.

Does rewinding for a number of factories in the country; has an incandescent drying cabinet and a testing bench for alternators, 57 kw.

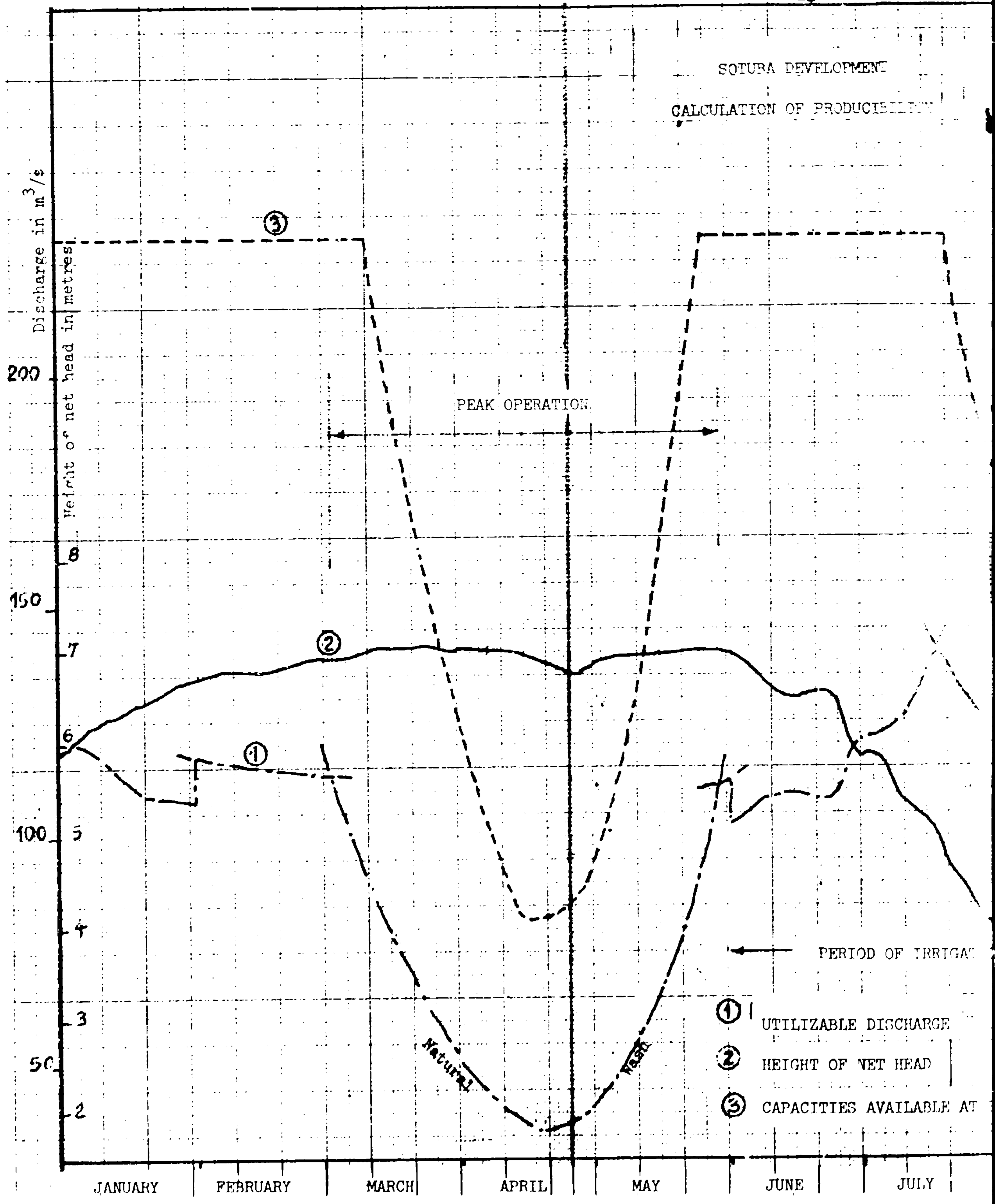
Refrigeration: A 22-kw compressor.

Foundry: Works in conjunction with the general machinery workshop to prepare castings from models provided by the model-preparation workshop.

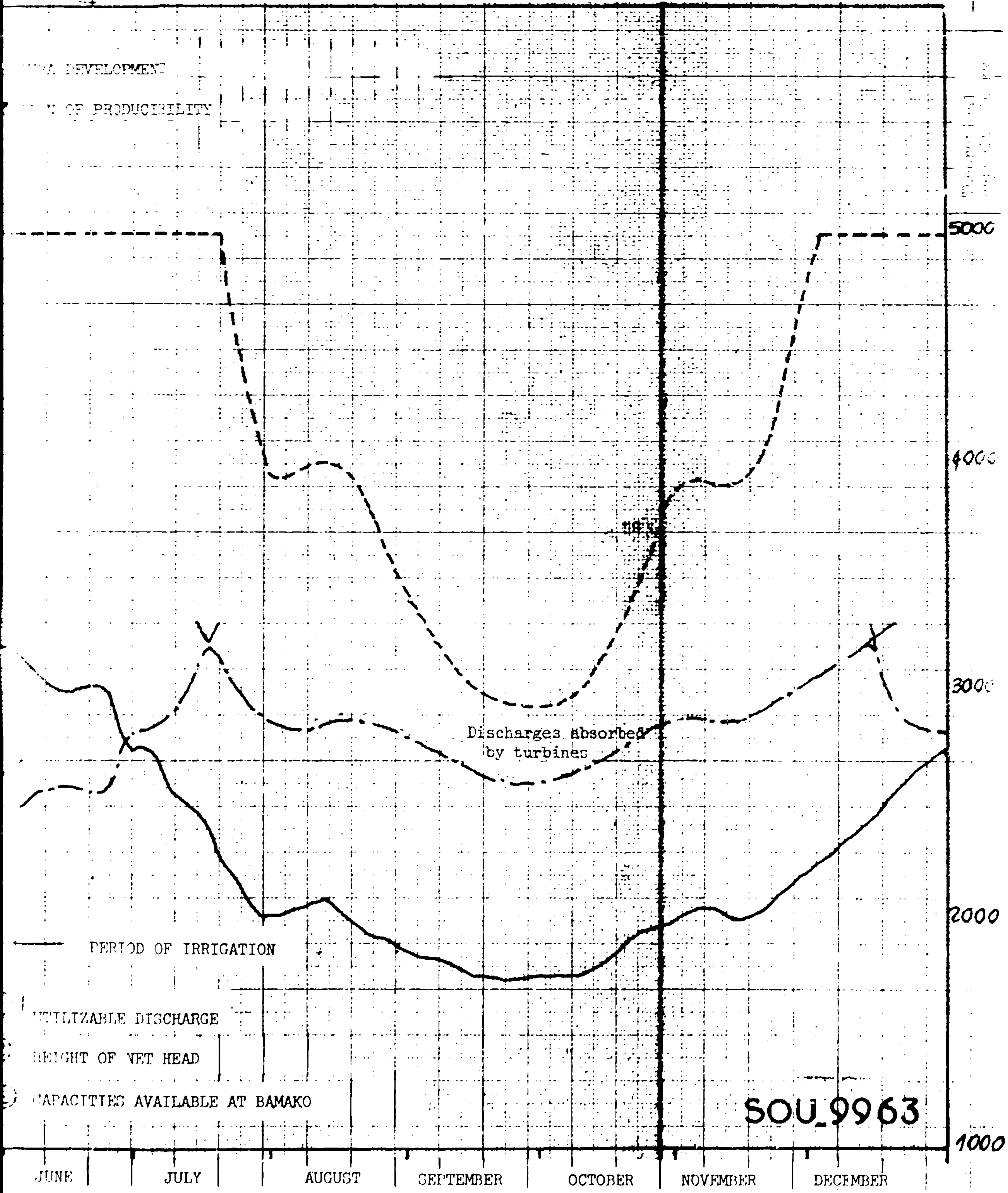
One incandescent Mazière oven, about 150 kw
One cupola furnace for iron casting
Two ovens, for metals and light alloys
One incandescent core stove

Metal doorframes:

One flanging machine 17 kw
One compressor 15 kw
One Promécam bender 10 kw.


SOTUBA DEVELOPMENT
CALCULATION OF PRODUCIBILITY
Discharge in m^3/s
Height of net head in metres
200
150
100
50
8
7
6
5
4
3
2
PEAK OPERATION
PERIOD OF IRRIGAT
Natural
Wash
① UTILIZABLE DISCHARGE
② HEIGHT OF NET HEAD
③ CAPACITIES AVAILABLE AT
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY

SECTION 1


...A DEVELOPMENT
...OF PRODUCIBILITY
5000
4000
3000
2000
1000
Discharges absorbed by turbines
PERIOD OF IRRIGATION
UTILIZABLE DISCHARGE
HEIGHT OF NET HEAD
CAPACITIES AVAILABLE AT BAMAKO
SOU_9963
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

SECTION 2