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COMPARISONS OF CAPACITY, INVESTMENT AND MAINTENANCE COSTS FOR MANUALLY OPERATED STANDARD MACHINES, MECHANIZED MACHINES AND AUTOMATIC MACHINE SYSTEMS *

by

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C O N T E N T

Introduction

For every investment scheme, whether it is a complete factory, a detailed production plant or a single machine, the first question concerns the productivity of such.

Productivity is the relationship of the Production Capacity to the expenditure and is taken as a guide for the economical use of the investment.

For practically all technical processes within the production different technologies can be applied, ranging from the simplest manual operation up to fully automatic processes. The planners and investors of a company have to deal with a difficult decision in selecting the manufacturing technology operations and facilities to achieve highest productivity for the required capacity.

This paper shows a way of recognising and justifying criteria in selecting production facilities for factories of different sizes and with different objectives of varying importance.

1. Marketing Consideration

Which quantity of the envisaged product is marketable results in the planned capacity which is the base for determining the production equipment requirements and its maximum utilisation.

2. Infra-structural Consideration

The supply of raw material and energy must be ensured for the planned production capacity.

3. Labour force consideration

It has to be ensured that sufficient skilled labourers, machine operators and technicians are available for operating and maintaining the equipment. The question of available training possibilities in the country has also to be taken into consideration. Otherwise expensive foreign specialists have to be employed.

4. Economic consideration

Should the planned investment be based on labour-intensive operations to solve local population problems in order to broaden general standards or should a higher capacity be achieved through higher commercial efficiency?

Especially in developing countries, severe mistakes have been experienced by installing highly mechanised production facilities which are under-utilized owing to the planned capacity not being suitable for the market and the produced amount not being sold.

Minor mistakes in operating sensitive, highly mechanised automated machines can stop the production for several days, when the qualifications of the maintenance personnel cannot cope with the repair requirements, being unable to localise and correct machine troubles in time. Interruption in the production flow through lack of material or power supply are well known weaknesses in the industry in developing countries.

The main problem usually is the lack of qualified operators.

Such an investment can also loose its objective when in developing countries, for example five foreign specialists and ten local workers are operating the factory while hundreds of the labour force are without a job.

The maintenance, servicing and care of such equipment is in this case of great importance. A specialized fitter cannot be made available at short notice from a country many flight hours away for trouble-shooting and machine repair. A domestic maintenance team should be immediately available, generally trained abroad, to be able to deal with at least common machine troubles.

Apart from the necessity to maintain a good stock of spare parts and operating services, one should work on the basis that for standard machines such as circular saw benches or planers, etc., a spare part stock of 5 - 7 % of the investment cost is available. Automated machines with electronic control need a calculated spare parts stock in the range of 12 - 15 %.

Generally speaking, the higher the technical level of a plant, i.e. the mechanisation an automisation, the higher are also the market demands, the in ra-structure and the personnel, in which case the different subject have to be considered very carefully, in order to achieve an optimum decision.

All these criteria serve to influence the cost structure expressed in monetary terms. One can estimate the costs required which is a base for strict decisions.

The returns obtained through product sales are giving the requirement on the fixed capital for labour force and energy expenses. The costs are divided into fixed e.g. time dependent units such as capital costs and fixed overhead costs; and variable e.g. quantity dependent units for wages and energy as well as the varying general costs. Each individual production plant is limited within its capacity.

5. Comparison of three different plant capacities

In the following examples, an investment decision is simulated. A factory, with a planned capacity of 600 production units per day. Three different production units per day. Three different production techniques with three comparable production facilities are applied.

5.1 Capacity 400 units per day;
Manually operated standard machines; ANNEX I
Fixed costs DM 40 per day;
Variable cost DM 0,40 per production unit;

5.2 Capacity 400 units per day;
Semi-mechanised equipment; ANNEX II
Fixed costs DM 150 per day;
Variable costs DM 0,30 per production unit;

5.3 Capacity 1,000 units per day;
Fully-automatic equipment; ANNEX III
Fixed costs DM 250 per day;
Variable costs DM 0,20 per production unit.

Each of these three possibilities has its break-even point

The plant No. 1 shows 140 units per day giving a relatively low break-even point, which, however, is insufficient in the total capacity as 200 units per day cannot be realised.

The plant No. 2 shows a minimum production of 410 units per day and has a non-utilised capacity of 200 units per day.

The plant No 3 shows the break-even point by 510 units per day, which causes a non-realised capacity of 400 units.

Plant No. 1 has therefore the lowest total costs per unit and thus the best productivity. The problem there lies only in the lack of capacity. The diagram (Annex IV) covers two plants of type No. 1, which render it possible to fullfil the required capacity.

The break-even point is at a production rate of 280 units per day, of which 200 units per day are non-realised capacity. The diagram (ANNEX V) covers all four variations in combined order. It states that Plant No. 1 has the best productivity value for the demand. The total cost graph is shown over the variations 2 and 3. Foremost, at a daily production rate of more than 750 units Plant No. 3 is better than Plant No. 2 at a daily capacity of more than 200 units; Plant No. 3 is still better than Plant No. 2 and at a daily production rate of more than 900 units Plant No. 3 is even better than Plant No. 4.

This example is of course constructed in a abstract manner. It simply shows a method which allows for selecting the right equipment for a definite planned capacity, on given variations of which the fixed and variable costs are known.

In this special case, the only recommendation can be to start with an equipment like plant 1, and to increase plant 4 when the necessity is given.

6. Capacity cost comparison

The following tables compare the more important operations in wood processing on different machines. This data is based on European cost relations which naturally have to be adjusted accordingly to the situation in developing countries.

6.1 Panel subdividing

COMPARISON OF CAPACITY AND COSTS

OPERATION **Panel subdividing**		A	B	C
MACHINE TECHNOLOGY APPLIED		vertical panel saw	semi-autom. panel saw	fully autom. double saw line
INVESTMENT COSTS AND INSTALLATION COSTS US$		22,000	70,000	190,000
POWER REQUIREMENT: ELECTRIC kW HEAT Kcal/h		4	11	26
MACHINE OPERATOR:	NUMBER	2	2	2
	QUALIFICATION	medium/low	med./low	high/low
MAINTENANCE COST PER YEAR US$		120	1,500	6,000
MAINTENANCE OPERATOR QUALIFICATION		medium	medium	high
AVERAGE MACHINE CAPACITY UNITS PER DAY		8 m^3	25 m^3	80 m^3
COSTS FIXED: AMORTISATION + OVERHEADS	$/DAY	95	145	275
VARIABLE: WAGES + OVERHEADS	$/PU	17	6	2
TOTAL COSTS PER PRODUCTION UNIT		29	12	5,40

Variation A: a vertical board cutting saw for manual loading

Operating Personnel 2: 1 machine operator, average qualifications with one helper;

Variation B: a pressure bar board sizing saw with scissor lift and mechanical board infeed against preset pneumatic stops;

Manual unloading of the cut boards;

Operating personnel 2: 1 machine operator and one helper;

Variation C: an angled combination consisting of two pressure bar saws, both fully numerically controlled board supply device. Material infeed via a scissors lift and feeding device, outfeed via roller ways and stacking device. Board remnants are removed by hand. Operating personnel 2: 1 machine operator and one helper.

Example:	Reduced capacity	8 m3	25 m3
	Total costs per P.U.	24.00	13.00

6.2 Panel veneering

DESCRIPTION OF CAPACITY AND COSTS

OPERATION: **Panel veneering**	A	B	C
MACHINE TECHNOLOGY APPLIED	single daylight press	six daylight press	cycling single daylight press with autom. loading/unloading
INVESTMENT COSTS AND INSTALLATION COSTS US$	38,000	80,000	135,000
POWER REQUIREMENT: ELECTRIC kW HEAT Kcal/h	25	8 60,000	22 80,000
MACHINE OPERATOR: NUMBER	2	3	2
MACHINE OPERATOR: QUALIFICATION	med/low	med/med/low	med/high
MAINTENANCE COST PER YEAR US$	250	2,400	7,000
MAINTENANCE OPERATOR QUALIFICATION	low	low	high
AVERAGE MACHINE CAPACITY UNITS PER DAY	200 m^2	1200 m^2	1600 m^2
COSTS FIXED: AMORTISATION + OVERHEADS $/DAY	110	155	215
VARIABLE: WAGES + OVERHEADS $/PU	0,70	0,20	0,08
TOTAL COSTS PER PRODUCTION UNIT	1,25	0,33	0,22

Variation A: one single daylight press, electrically heated with a simple roller glue spreader;

Operating personnel 2: 1 machine operator and one helper.

Manual loading and unloading.

Variation B: a six daylight press, steam heated to 95°C with roller glue spreader and disc roller way to the lay-up station.

Manual loading of glue spreader and unloading to a rack;

Operating personnel 3: 1 machine operator, two helpers.

6.2 Panel veneering

Variation C: automatic cycling single daylight pressing line
1 scissors lift with board infeed;
1 brushing machine (surface cleaning);
1 four roller glue spreader linked to disc roller way;
fully automatic short cycle veneering press with infeed and outfeed belt linked with stacking device;
steam heated 140°C.

Stock travelling on roller ways;
Veneer store on a veneer bridge on top of the lay up table;
Operating personnel 2: 1 machine operator, one helper.

Example:	**Reduced capacity**	200 m2	1,200 m2
	Total costs per P.U.	0.97	0.26

6.3 Panel sizing

COMPARISON OF CAPACITY AND COSTS

OPERATION: **Panel sizing**		A	B	C
MACHINE TECHNOLOGY APPLIED		panel circular saw bench	double circ. saw with sliding table	double end tenoner
INVESTMENT COSTS AND INSTALLATION COSTS US$		11,000	20,000	75,000
POWER REQUIREMENT: ELECTRIC kW HEAT Kcal/h		6	12	34
MACHINE OPERATOR:	NUMBER	1	1	2
	QUALIFICATION	medium	medium	med/low
MAINTENANCE COST PER YEAR US$		100	250	3,500
MAINTENANCE OPERATOR QUALIFICATION		low	low	medium
AVERAGE MACHINE CAPACITY UNITS PER DAY		250 m^2	900 m^2	2,500 m^2
COSTS FIXED: AMORTISATION + OVERHEADS	$/DAY	92	115	175
VARIABLE: WAGES + OVERHEADS	$/PU	0,27	0,09	0,06
TOTAL COSTS PER PRODUCTION UNIT		0,64	0,22	0,13

Variation A: sizing circular saw bench with sliding table, operated manually manually by one trained worker.

Variation B: double circular saw with scoring saws and sliding table;
Operating personnel 1: one trained worker for double loaded stock (two boards);

Variation C: simple double end tenoner (double edge saw with chain feed) electro-mechanically controlled.
Operating personnel 2: 1 machine operator, one helper;
Stock travels on roller ways.

Example:	Reduced capacity	250 m2	900 m2
	Total costs per P.U.	0.55	0.25

6.4 Sizing and edge banding

COMPARISON OF CAPACITY AND COSTS

OPERATION: Sizing and edge banding		A	B	C
MACHINE TECHNOLOGY APPLIED		double saw+ single edge bander	linked double ender+double edge bander	automatic sizing/ edge banding
INVESTMENT COSTS AND INSTALLATION COSTS, US$		65,000	155,000	265,000
POWER REQUIREMENT: ELECTRIC	kW	36	58	78
	HEAT Kcal/h			
MACHINE OPERATOR:	NUMBER	3	2	2
	QUALIFICATION	med/high/low	med/high	high/very high
MAINTENANCE COST PER YEAR US$		2,700	6,000	9,000
MAINTENANCE OPERATOR QUALIFICATION		medium	high	very high
AVERAGE MACHINE CAPACITY UNITS PER DAY		800 m^2	2200 m^2	4000 m^2
COSTS FIXED: AMORTISATION + OVERHEADS	$/DAY	135	220	380
VARIABLE: WAGES + OVERHEADS	$/PU	0,28	0,08	0,04
TOTAL COSTS PER PRODUCTION UNIT		0,45	0,18	0,14

Variation A: double circular saw in connection with a single end-edge banding machine;

Operating personnel 3: 1 machine operator on the double circular saw and 1 machine operator with one helper on the veneer edge bander.

Variation B: a double end tenoner with chain feed, electro-mechanised, linked with a double end veneer edge banding machine, equipped with a veneer or foil hopper feed, cut-off saw, flushing unit and edge sanding unit, all electro-mechanised control.

Operating personnel 2: 1 machine operator on the double end tenoner;
1 machine operator on the veneer edge banding machine;

Stock infeed and outfeed via roller ways, loaded manually.

6.4 Sizing and edge banding

Variation C: a fully automatic sizing edge banding machine
Vacuum loading device: combined with a rotating station for length-wise and cross-wise loading of the machine;
Panel sizing and veneer edge banding machine
4 milling units, pneumatically controlled. Veneer edge banding with edge hopper feed and a six-fold roll exchange magazine, cut-off saw, flushing unit and sanding unit;

All units are electronically controlled, with electronic width adjustment and automatic stacking device;

Operating personnel 1: Highly qualified machine operator.

Example:	Reduced capacity	800 m2	2200 m2
	Total costs per P.U.	0.35	0.21

6.5 Dowel hole boring

COMPARISON OF CAPACITY AND COSTS

OPERATION **Dowel hole boring**		A	B	C
MACHINE TECHNOLOGY APPLIED		standard boring machine m/o	semi-autom. boring machine	automatic dowel hole boring machine w.feed unit
INVESTMENT COSTS AND INSTALLATION COSTS US$		24,000	46,000	95,000
POWER REQUIREMENT: ELECTRIC kW HEAT Kcal/h		8	16	24
MACHINE OPERATOR:	NUMBER	1	1	1(linked)
	QUALIFICATION	medium	medium	high
MAINTENANCE COST PER YEAR US$		120	280	2,600
MAINTENANCE OPERATOR QUALIFICATION		low	low	high
AVERAGE MACHINE CAPACITY UNITS PER DAY		800 parts	1400 parts	7200 parts
COSTS FIXED: AMORTISATION + OVERHEADS	$/DAY	96	130	190
VARIABLE: WAGES + OVERHEADS	$/PU	0,17	0,11	0,07
TOTAL COSTS PER PRODUCTION UNIT		0,29	0,20	0,14

Variation A: simple standard dowel hole boring machine, equipped with swivelling boring bar for vertical and horizontal boring, 21 boring bit spindles; Operating personnel 1: machine operator;

Variation B: one automatic dowel hole boring machine with five vertical boring units and two horizontal boring units, manually loaded, no through-feed; Operating personnel 1: machine operator;

Variation C: one automatic dowel hole boring machine with cycling feed, five vertical boring units and two horizontal boring units, motor setting at digital readings. Cycling feed automatically controlled; loading via link conveyor belt; Automatic outfeed or via linked conveyor to sanding line.

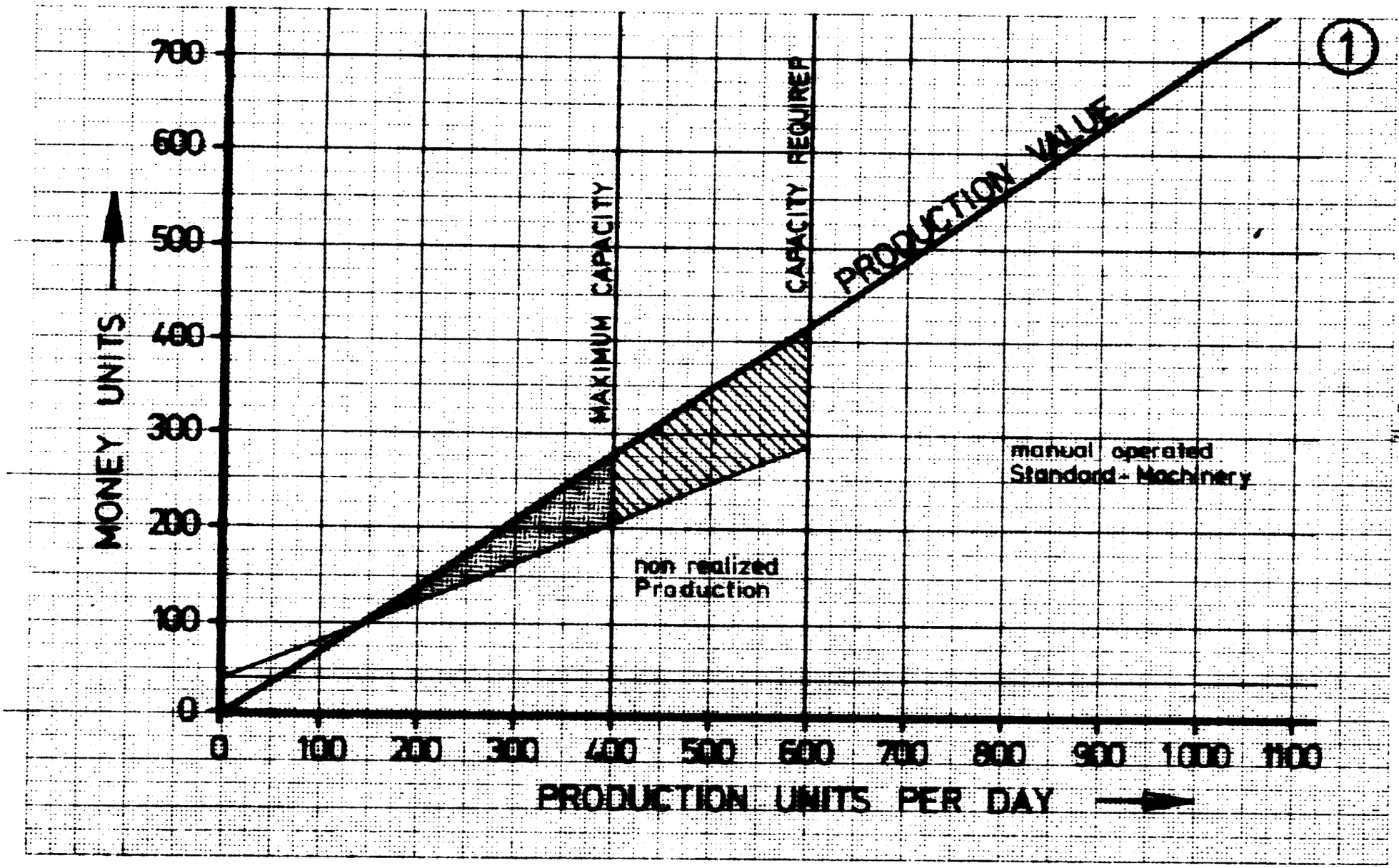
Example:	Reduced capacity	800 m2	1400 m2
	Total cost per P.U.	0.27	0.80

7. Conclusion

These comparisons show clearly that production costs on a highly automated equipment are the lowest. This, however, occurs only when the plant is utilised at its maximum capacity. If this is not possible, the total costs increase to the value shown in the examples below the tables 6.1 to 6.5. If the capacity of the panel sizing plant "C" (table 6.3) decreases from 2500 m2 to 900 m2 production per day, as in plant "B", the total costs then increase from US$ 0.13 to 0.25 per m2.

In this case, costs are even higher than the total cost of Variation B.

Finally, there is the flexibility of a production plant. The higher the level of automatisation the higher the specialisation of the product, the market and the working standard. Large fluctuations can be expected concerning the product, the design and the construction, the market reaction, in the amount for distribution and in working standards as well as in the availability of qualified labour. In this case, it is better to remain on a lower level of automatisation in order to keep these fluctuations within the range of the variable costs.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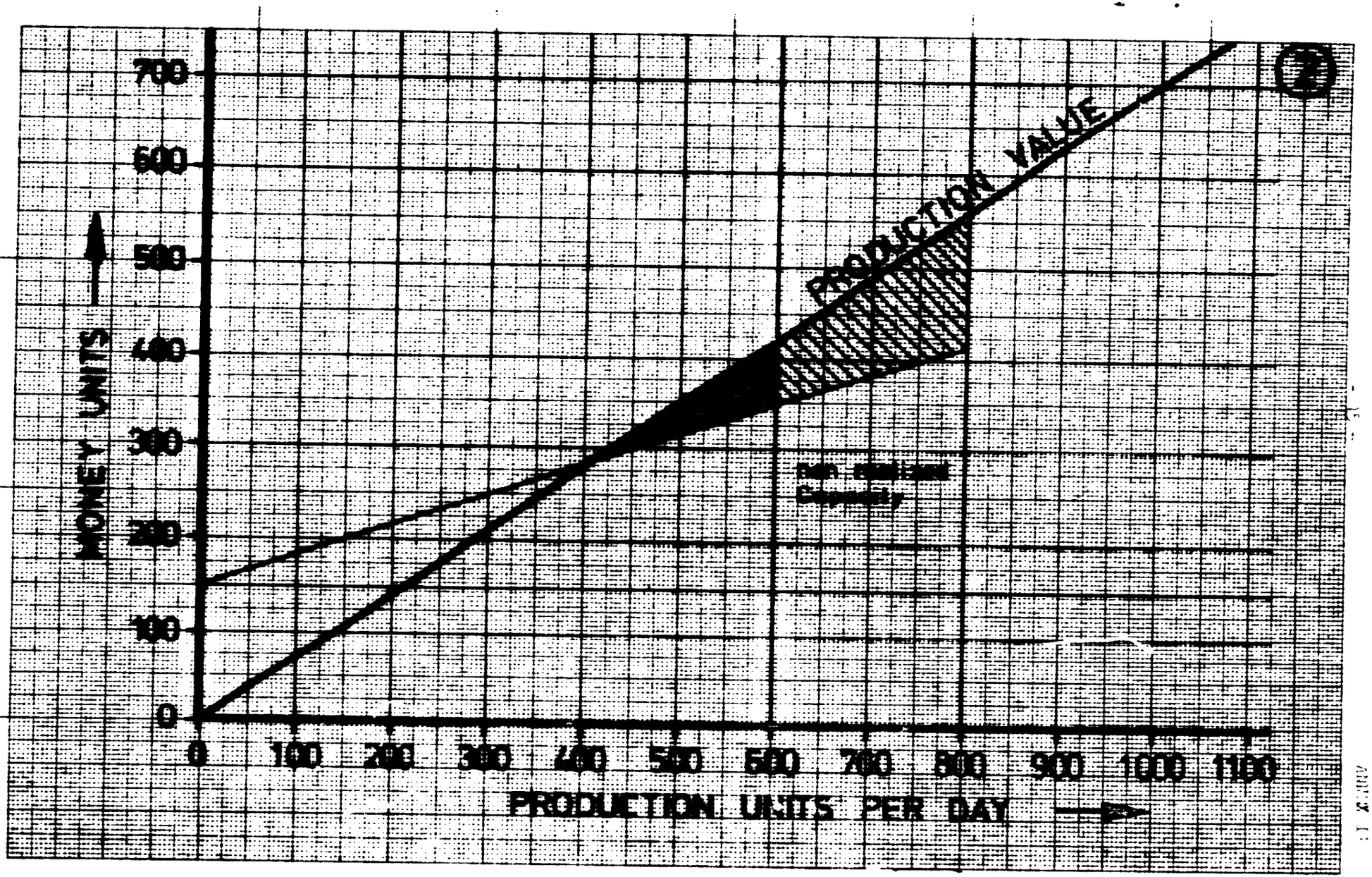
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
1100
PRODUCTION UNITS PER DAY
MAXIMUM CAPACITY
CAPACITY REQUIRED
PRODUCTION VALUE
manual operated
Standard - Machinery
non realized
Production

1

ANNEX I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MONEY UNITS
PRODUCTION VALUE
0
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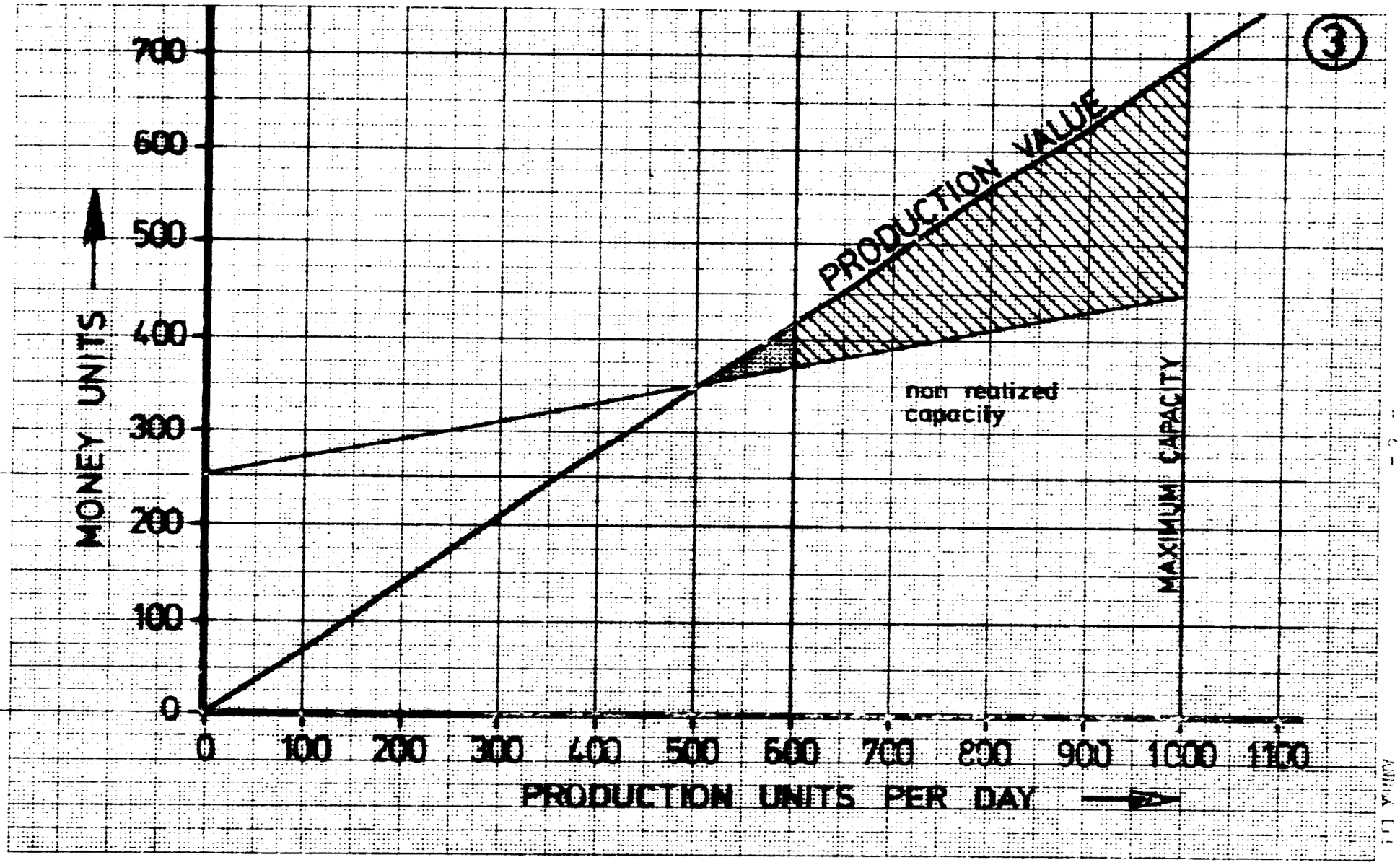
1100
PRODUCTION UNITS PER DAY


3
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600
500
400
300
200
100
0
MONEY UNITS
PRODUCTION VALUE
non realized capacity
MAXIMUM CAPACITY
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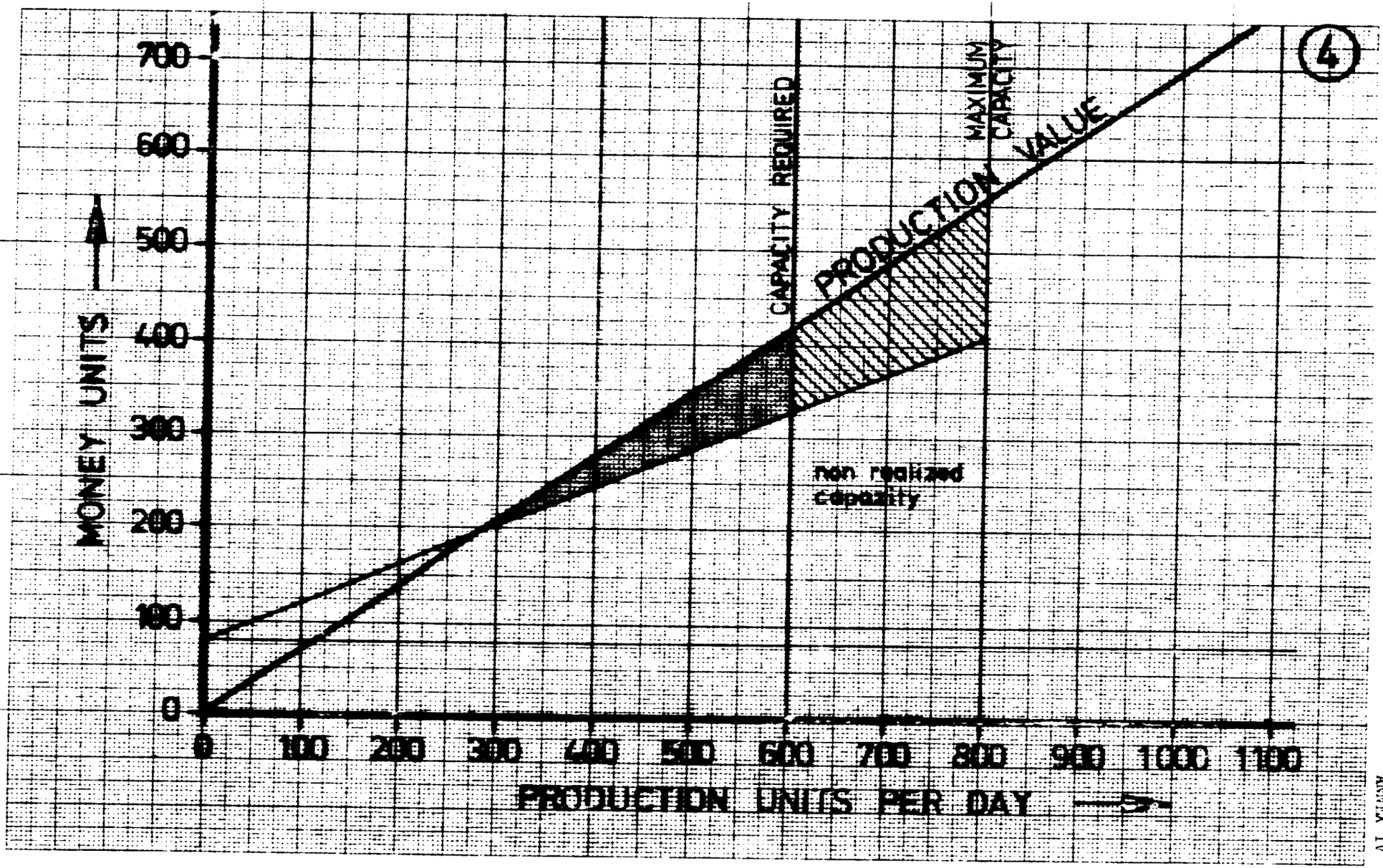
200
300
400
500
600
700
800
900
1000
1100
PRODUCTION UNITS PER DAY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MONEY UNITS
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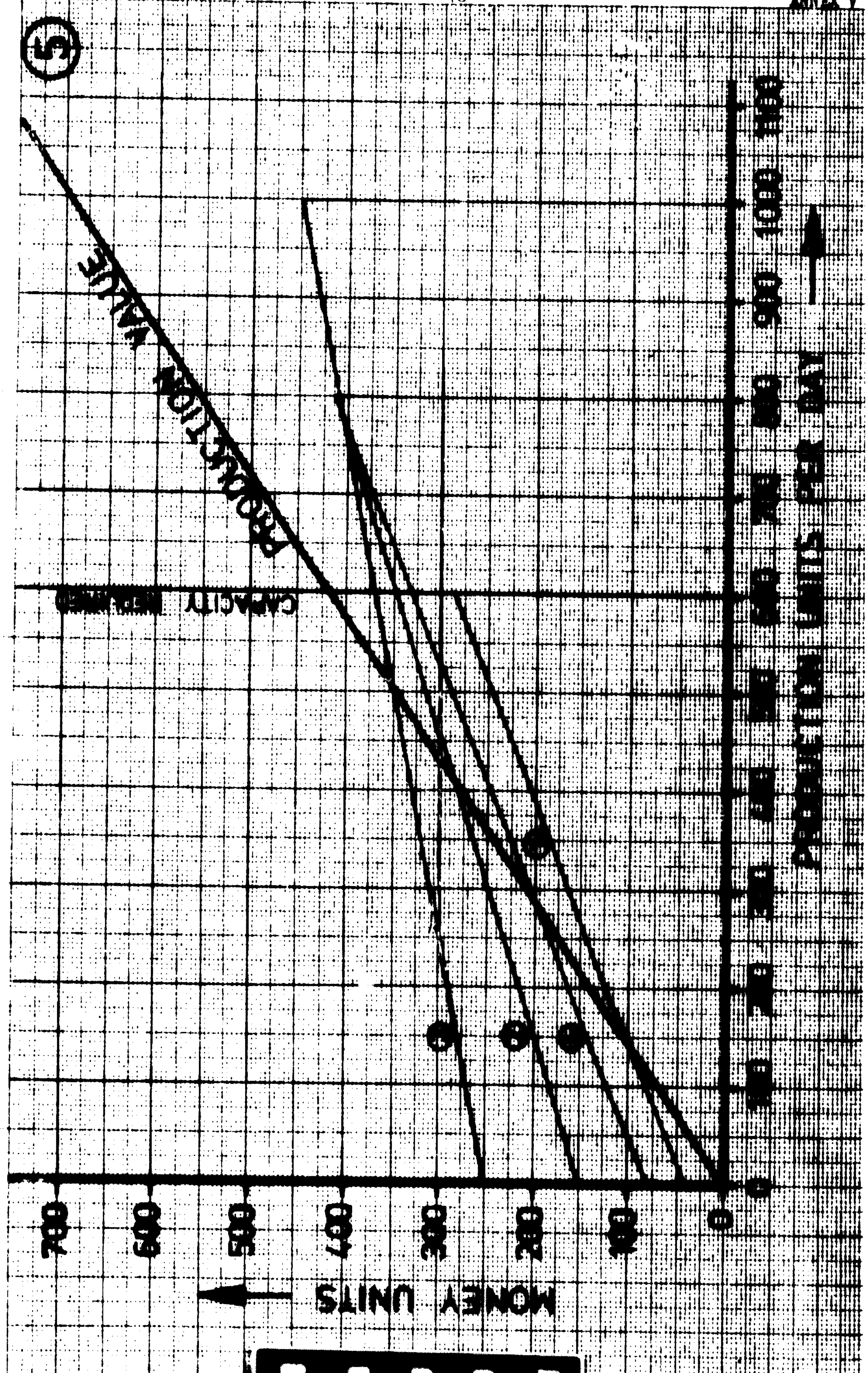
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
1100
PRODUCTION UNITS PER DAY
CAPACITY REQUIRED
MAXIMUM CAPACITY
PRODUCTION VALUE
non realized capacity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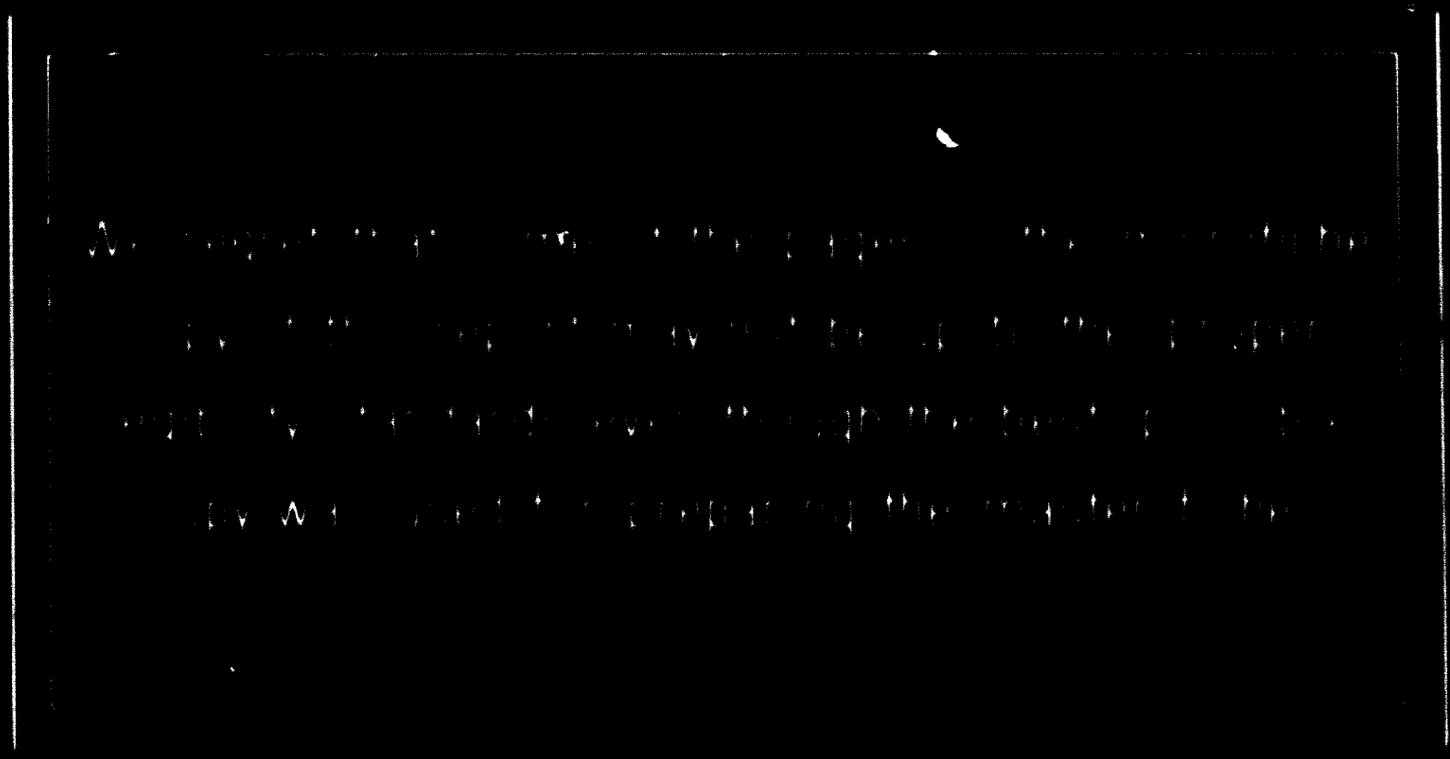
PRODUCTION VALUE
CAPACITY
PRODUCTION UNITS PER DAY
900
1000
MONEY UNITS
0
100
200
300
400
500
600
700



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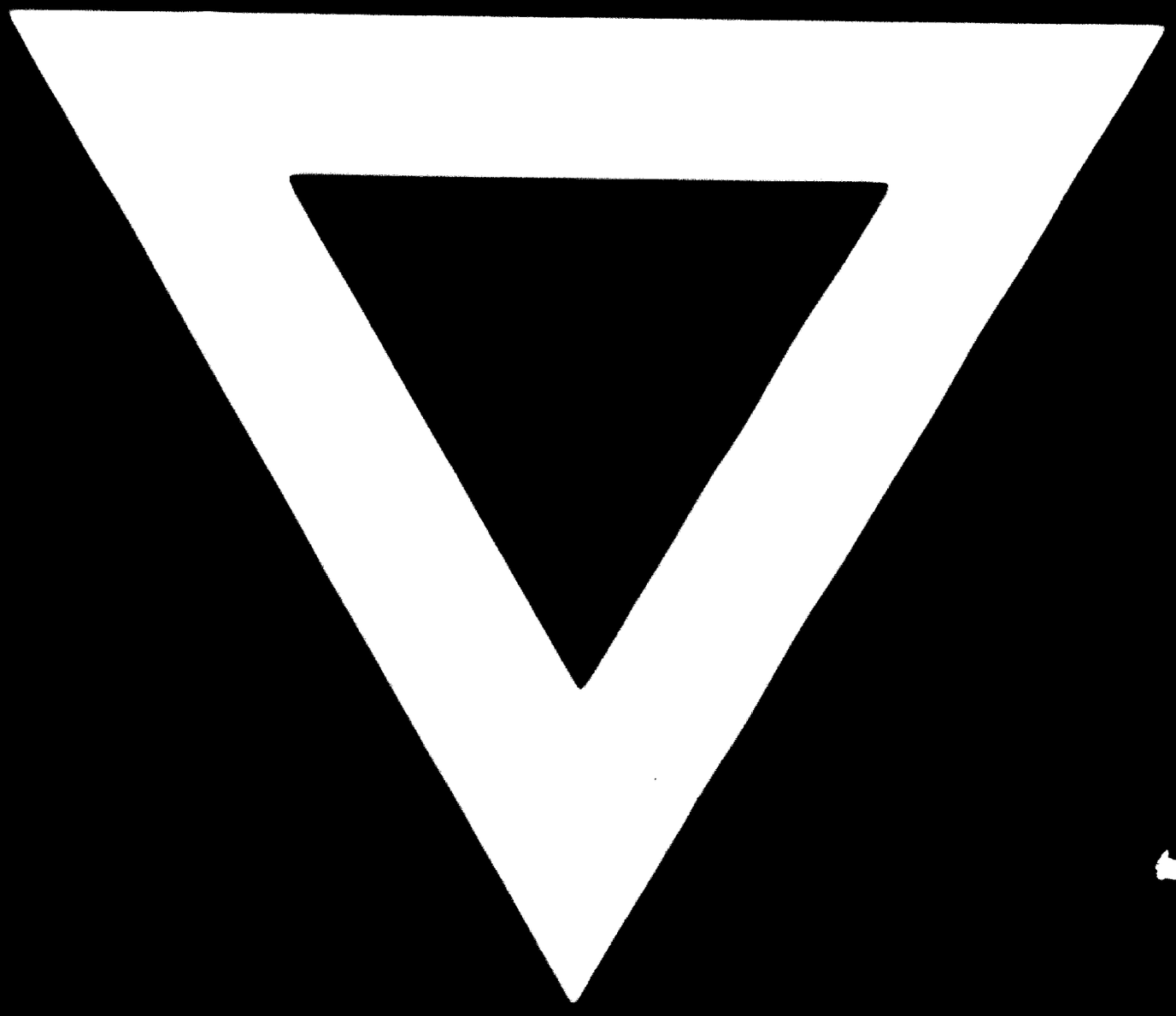

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