STRATEGIC PLANNING FOR COST REDUCTION IN AN ENGINEERING COMPANY

in Two Volumes

VOLUME II

Patricia Jean Thornley

Submitted for the higher degree of
Doctor of Philosophy
The University of Aston in Birmingham
June, 1982.

BEST COPY

AVAILABLE

Variable print quality

DAMAGED

TEXT

IN

ORIGINAL

Text cut off in original

Page No.

VOLUME II (Volume II)

APPENDICES

Page No.

Page No.

LIST OF TABLES

VOLUME II

APPENDICES

APPENDIX A

		Page No.

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX F

APPENDIX K

Page No.

APPENDIX L

LIST OF GRAPHS

VOLUME II

APPENDICES

VOL.II. Page No.

APPENDIX C

APPENDIX D

Page No.

APPENDIX H

Appendix A

Simulated forecasts for years 1974/78 for the three strategic options given in BOC Arc Equipment plans, using alternative estimates of the parameter of the experience curve model.

Index

Tables

Appendix A

Simulated forecasts for years 1974/78 for the three strategic options given in BOC Arc Equipment plans, using alternative estimates of the parameter of the experience curve model

The three strategic options for the MIG product group proposed in plans made in 1972/73 were to retrench for generation of immediate profits, continue on the current path to achieve some growth with some profits, or to expand to a position of co-dominance in European markets.

These options were evaluated using forecasts of sales, estimated investment costs and fixed costs, and projections of production costs using an experience curve model with 80% 'slope'. (See below)

The parameters used as a basis for the choice of option from the evaluation appeared to be those of profit, cash flow and return on capital employed. (ROCE)

The purpose of this exercise was to use the same projections of sales revenue, investment costs and fixed costs, but to estimate production costs based on experience curve models with parameters of 70% and 90% respectively. Results could be used to judge whether the alternative evaluations using different parameters would have led to a different choice of option, based on the given parameters.

A.1 Method

Since the original calculations were not available, there were a few problems involved.

The experience curve model has equation

$$C = aV^{-b}$$

where C = unit cost, V cumulative output and a, b are parameters of the model.

This will be used in the form

$$\frac{C_2}{C_1} = \frac{(V_1)^b}{(V_2)}$$

where C_1 V_1 are unit cost and cumulative output in year 1

C_2 V_2 " " " " " " " " 2

Thus the only parameter needed is the value of b.

Since slopes of the curve have been specified as 70%, 80%, 90%, the values of b can be calculated for the relationship

$$\text{slope} = \frac{1}{2^b} \text{ expressed as a percentage.}$$

In order to calculate new values for unit cost, the original unit cost in year 1 (1972/73) was required, and also the cumulative output of production for year 1 and each subsequent year for which predictions were to be made.

The only information available was the following:

i) Values of BOC AE sales, fixed costs and production costs for 1972/73 and forecasts for 1973/74 to 1977/78.

ii) An estimated slope of 83% for the experience curve model for UK average price of a MIG rectifier. (est by BCG)

iii) Estimated UK industry output for 1972/73 .

iv) Projections for GDP for 1973/74 to 1977/78, found in some BCG literature.

Thus, in order to be able to calculate revised unit costs of production for BOC AE for each year of the plan, estimates were required for the volumes of production projected for each year of the plan under each option, and some estimate of the cumulative output in 1972/73. Volumes could then be used to estimate the unit cost of production in year 1, and subsequent values for cumulative output for each year.

If volumes of sales were used to represent volumes of production, these could be calculated from value of sales, if an estimate of the average price was available for each year. Under the assumption of an experience curve model operating for average price, this could not be taken as a constant value, and so had to be estimated from the 83% slope experience curve model suggested by BCG. This in turn required estimates of industry cumulative output in 1972/73, and projections for subsequent annual volumes of output. This was done using the current estimates of 15% annual growth rate for the market.

Thus, the main steps in the process were as follows:

a) Assuming market growth rate for MIG of 15% p.a., and average price (deflated) to be modelled by experience curve model with 83% slope, and using an estimated cumulative output of

MIG sets for the industry in 1972/73, calculate projections for the average price of a MIG set for each year of the plan. This will then be converted back into real money terms, using the projections of the GDP index.

b) Use the average price in real value terms to convert forecasts of BOC AE sales revenue to volumes of sales, for each option and each year of the plan.

c) Estimate cumulative output of MIG sets for BOC AE for the beginning of the period, 1972/73, and calculate cumulative output for each year of the plan, for each option, using the results from (b).

d) For each option, and using models with 70%, 80%, and 90% slopes respectively, calculate the unit cost of production of MIG sets for each year of the plan, using estimates of cumulative output form (c). Multiply these values by the number of units from (b) to obtain total production costs, which will be in constant value terms and so must be inflated using the projections for GDP.

e) Use the resulting projections for total production cost, in real terms, with forecasts of sales, fixed costs, cash flow and capital employed to calculate revised estimates of profit, cash flow and ROCE for each option under each model.

A.2 Calculations

Calculations are given under steps (a) to (e) described in A.1

(a) Projections for average price of a MIG set for each year of the plan. (1973/74 to 1977/78)

Assumptions

i) Average price of a MIG rectifier is declining in constant money terms, and can be modelled by an experience curve of 83%. (parameters b = 0.269)

ii) The UK MIG market will continue growing at 15% p.a. in volume terms, output in 1972/73 was 5150.

iii) Cumulative output of the UK MIG can be estimated by taking six times the annual output, given as 5150 units in 1972/73. (source-some work by BCG found amongst strategic plans).

iv) Projections for GDP index for 1973/74 to 1977/78 are those used in BCG calculations. (Source-same as in iii).

v) Average price of a MIG rectifier in real terms in 1972/73 is £1183, £739 when deflated using GDP.

Calculations of UK industry output, cumulative output and average price

Table 1

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Vol of output (units)	5150	5922	6811	7832	9007	10358
cum output (units)	30900	36822	43633	51465	60472	70830
Average price (const money terms) £	739	705	674	644	617	591

Conversion of UK average price to real money terms (ie current value)

Table 2

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Inflating index	1.6	1.68	1.76	1.85	1.95	2.04
Ave price (current val) £	1183	1185	1186	1192	1203	1206.5

b) Conversion of forecasts of BOC AE sales revenue to sales volume, using estimates of average price. (Units = $\frac{\text{Sales val}}{\text{Ave price}}$)

Table 3

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Forecasts of Sales value (£'000)						
RETRENCH	1929	2483	2500	2500	2600	2600
CURRENT	1929	2483	2916	3391	3891	4463
EXPAND	1929	2650	3550	5100	6950	9000
Ave price (see a) £	1183	1185	1186	1192	1203	1206.5
Vol Forecasts (units)						
RETRENCH	1631	2096	2108	2097	2161	2155
CURRENT	1631	2096	2459	2844	3234	3699
EXPAND	1631	2237	2994	4278	5776	7460

c) Calculation of cumulative output for BOC AE using estimated cumulative output for 1972/73 (6x volume of output), and annual volumes of output estimated in (b).

Table 4

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
Cum output (units)						
RETRENCH	9786	11882	13990	16087	18248	20403
CURRENT	9786	11882	14341	17185	20419	24118
EXPAND	9786	12023	15017	19295	25071	32531

d) Calculation of the average unit cost of production of a MIG set for BOC AE for each year of the plan and each option, using models with three differing parameters.

70%,	parameter	b	=	.515
80%,	"	b	=	.322
90%,	"	b	=	.152

The initial unit cost for 1972/73 in constant money terms, is obtained from the total cost of production for that year, £965,000, divided by the volume of output.

Unit cost for each year is then multiplied by the volumes of output from (b) to give total cost of production, which is then inflated to current value terms using projections of GDP.

d) Calculation of total cost of production for BOC AE

Table 5 (a)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
All in £'000						
1) RETRENCH OPTION						
i) 90% curve (p=.152) Unit cost (const money)	.370	.359	.350	.343	.337	.331
Total cost (const money)	603	753	739	719	727	713
Inflated to real terms	965	1265	1300	1331	1418	1455
ii) 80% curve (p=.322) Unit cost (const)	.370	.348	.330	.315	.303	.292
Total cost (const)	603	728	695	661	654	629
Inflated to real terms	965	1224	1223	1223	1276	1284
iii) 70% curve (p=.515) Unit cost (const)	.370	.335	.308	.286	.268	.253
Total cost (const)	603	702	649	601	580	546
Total cost (real terms)	965	1179	1142	1111	1131	1114

Table 5(b)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
£'000						
2) CURRENT						
i) 90% curve (p=.152)						
Unit cost (const)	.370	.359	.349	.340	.331	.222
Total cost (const)	603	753	858	966	1070	1193
Total cost (real terms)	965	1265	1511	1787	2086	2434
ii) 80% curve (p=.322)						
Unit cost (const)	.370	.348	.327	.309	.292	.277
Total cost (const)	603	728	804	878	944	1024
Total cost (real)	965	1224	1416	1624	1841	2088
iii) 70% curve (p=.515)						
Unit cost (const)	.370	.335	.304	.277	.253	.233
Total cost (const)	603	702	747	787	819	860
Total cost (real)	965	1179	1315	1457	1598	1755

Table 5(c)

£'000	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
3) EXPAND						
i) 90% curve (p=.152)						
Unit cost (const)	.370	.359	.347	.334	.321	.308
Total cost (const)	603	802	1038	1428	1852	2300
Total cost (real)	965	1348	1827	2641	3612	4691
ii) 80% curve (p=.322)						
Unit cost (const)	.370	.346	.322	.297	.273	.251
Total cost (const)	603	775	965	1272	1579	1875
Total cost (real)	965	1301	1699	2353	3078	3825
iii) 70% curve (p=.515)						
Unit cost (const)	.370	.333	.297	.261	.228	.199
Total cost (const)	603	744	874	1116	1316	1487
Total cost (real)	965	1250	1538	2064	2567	3033

g) <u>Calculation of profits, cash flow and ROCE for each option under each slope curve.</u>

Notes: i) Forecasts of sales, fixed costs, capital investment and cash flow provided by the strategic review.

ii) New estimates of total production costs from results of (f) used to calculate new profit levels and adjust cash flow. In absense of any other information.

New cash flow = old cash flow - old profit and new profit.

iii) New estimates of profit used to calculate ROCE on original forecasts for capital invested.

Table 6(a)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
£'000						
1) RETRENCH OPTION						
SALES	1929	2483	2500	2500	2600	2600
FIXED COSTS	848	1013	972	916	895	877
PROD COSTS:						
a) 90% curve	965	1265	1300	1331	1418	1455
b) 80% curve	965	1224	1223	1223	1276	1284
c) 70% curve	965	1179	1142	1111	1131	1114
PROFIT						
a) 90% curve	116	205	228	253	287	268
b) 80% curve	116	246	305	361	429	439
c) 70% curve	116	291	386	473	574	609
CASH FLOW						
a) 90% curve	68	30	183	213	237	278
b) 80% curve	68	71	260	321	379	449
c) 70% curve	68	116	341	433	524	619
CAPITAL INV	10	10	10	10	10	10
CAPITAL EMP	1236	1360	1445	1445	1455	1465
ROCE						
a) under 90% curve	9.4%	15%	16%	17%	20%	18%
b) under 80% curve	9.4%	18%	21%	25%	29%	30%
c) under 70% curve	9.4%	21%	27%	33%	39%	42%

Table 6(b)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
£'000						
2) CURRENT OPTION						
SALES	1929	2483	2916	3391	3891	4463
FIXED COSTS	848	1072	1252	1460	1689	1950
PROD COSTS						
a) under 90%	965	1265	1511	1787	2086	2434
b) under 80%	965	1224	1416	1624	1841	2088
c) under 70%	965	1179	1315	1457	1598	1755
PROFIT						
a) under 90%	116	146	153	144	116	79
b) under 80%	116	187	248	307	361	425
c) under 70%	116	232	349	474	604	758
CASH FLOW						
a) under 90%	(42)	(164)	(77)	(127)	(144)	(211)
b) under 80%	(42)	(123)	18	37	101	135
c) under 70%	(42)	(78)	119	204	344	468
CAPITAL INV	40	160	60	60	60	60
CAPITAL EMP	1251	1460	1725	1975	2240	2515
ROCE						
a) under 90%	9.3%	10%	9%	7%	5%	3%
b) under 80%	9.3%	13%	14%	16%	16%	17%
c) under 70%	9.3%	16%	20%	24%	27%	30%

Table 6(c)

£'000	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
3) EXPAND OPTION						
SALES	1929	2650	3550	5100	6950	9000
FIXED COSTS	848	1491	2193	2362	2523	2770
PROD COSTS						
a) under 90%	965	1348	1827	2641	3612	4691
b) under 80%	965	1301	1699	2353	3078	3825
c) under 70%	965	1250	1538	2064	2567	3033
PROFIT						
a) under 90%	116	(189)	(470)	97	815	1539
b) under 80%	116	(142)	(342)	385	1349	2405
c) under 70%	116	(91)	(181)	674	1860	3197
CASH FLOW						
a) under 90%		(899)	(1300)	(933)	(395)	249
b) under 80%		(852)	(1172)	(645)	139	1115
c) under 70%		(801)	(1011)	(356)	650	1907
CAPITAL INV		540	400	300	290	230
CAPITAL EMP		2050	2815	3745	4865	6115
ROCE						
a) under 90%				3%	17%	25%
b) under 80%				10%	28%	39%
c) under 70%				18%	38%	52%

A.3 Results

Table 7 contains a summary of values obtained for the main criteria used in evaluating the choice of options. In Table 8 these are summarised further by calculating total profit over the 5 years, total investment over the five years, maximum capital invested, and an assessment of the positions on cash flow and return on capital employed over the planning period.

The bases for choice of strategy, and recommended options under each evaluation (using 90%, 80% and 70% experience curve models) are given below:

Strategic choices between each of the three alternative options under each model

1) Under 90% experience curve model

Retrench; total profit over period £1.2m, with only £50,000 investment. Positive cash flow throughout, ROCE increases from 15% in 1974 to 20% in 1978.

Current path; total profit over period £0.64m, capital investment totals £440,000. Cash flow negative throughout, ROCE declines from 10% in 1974 to only 3% by 1977/78.

Expand; total profit over period £1.8m, but with capital investment of £1.8m. Resulting cash flow negative until 1977/78. ROCE non-existent until 1975/76 builds up to 25% by 1977/78.

Choice; On a 5 year planning period, the choice must be to Retrench, giving good profit and cash generation.

Long term considerations; if the business is required to survive, another option may be necessary; the current path option looks disastrous with negative cash flow and declining ROCE; the expand path needs enormous funding for four to five years of the plan, but could produce good results thereafter.

2) Under 80% experience curve model

Retrench; Total profit over period £1.8m, with only £50,000 capital investment. Cash flow good, ROCE increases from 18% to 30% by 1977/78.

Current path; Total profit over period £1.5m, £440,000 capital investment. Cash flow positive after first year, ROCE increases from 13% to 17% by 1977/78.

Expand; Total profit over period £3.6m, with £1.8m capital investment required. Cash flow negative for first three years, then increases rapidly. ROCE non-existent until 1975/76, then increases to 39% by 1977/78.

Choice; If funding allows, the expand option should be chosen both on total profit and ROCE.

NB Needs heavy funding over first three years. If funding not available, retrench provides good cash generation.

Long term considerations; if business is required to survive, current path option provides growth-with some profit over period. ROCE increasing.

3) Under 70% experience curve

Retrench; Total profit over period £2.3m, with £50,000 capital investment required. Cash flow positive throughout. ROCE increases from 21% to 42% by 1977/78.

Current path; Total profit over period £2.4m, £440,000 total capital investment required. Cash generated after first year, ROCE increases from 16% to 30% by 1977/78.

Expand; Total profit over period £5.5m, with £1.8m required for capital investment. Cash flow negative until fourth year of plan, then cash generated; ROCE negative until 1975/76, increases to 52% by 1977/78.

Choice; If funding allows, the expand alternative is the best both for profit, ROCE and longer term considerations.

Current path meets requirements for profit generation and ROCE.

Long term considerations; Expand option if funding allows, otherwise current path shows signs of increasing profit with growth.

SUMMARY OF CRITICAL FACTORS IN FORECASTS

Table 7(a)

		1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
1) RETRENCH							
SALES		1929	2483	2500	2500	2600	2600
PROFIT -	90%	116	205	228	253	287	268
	80%	116	246	305	361	429	439
	70%	116	291	386	473	574	609
CASH FLOW-	90%	68	30	183	213	237	278
	80%	68	71	260	321	379	449
	70%	68	116	341	433	524	619
CAP INV		10	10	10	10	10	10
CAP EMPL		1236	1360	1445	1445	1455	1465
ROCE	90%	9.4%	15%	16%	17%	20%	18%
	80%	9.4%	18%	21%	25%	29%	30%
	70%	9.4%	21%	27%	33%	39%	42%

Table 7(b)

	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
2) CURRENT PATH						
SALES	1929	2483	2916	3391	3891	4463
PROFIT - 90%	116	146	153	144	116	79
80%	116	187	248	307	361	425
70%	116	232	349	474	604	758
CASH FLOW 90%	(42)	(164)	(77)	(127)	(144)	(211)
80%	(42)	(123)	18	37	101	135
70%	(42)	(78)	119	204	344	468
CAP INV	40	160	60	60	60	60
CAP EMPL	1251	1460	1725	1975	2240	2515
ROCE						
90%	9.3%	10%	9%	7%	5%	3%
80%	9.3%	13%	14%	16%	16%	17%
70%	9.3%	16%	20%	24%	27%	30%

SUMMARY OF FINANCIAL FORECASTS, CONTINUED

Table 7(c)

		1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
3) EXPAND OPTION							
SALES		1929	2650	3550	5100	6950	9000
PROFIT -	90%	116	(189)	(470)	97	815	1539
	80%	116	(142)	(342)	385	1349	2405
	70%	116	(91)	(181)	674	1860	3197
CASH FLOW	90%	-	(899)	(1300)	(933)	(395)	249
	80%	-	(852)	(1172)	(645)	139	1115
	70%	-	(801)	(1011)	(356)	650	1907
CAP INV			540	400	300	290	230
CAP EMPL			2050	2815	3745	4865	6115
ROCE	90%				3%	17%	25%
	80%				10%	28%	39%
	70%				18%	38%	52%

SUMMARY OF OPTIONS under each model

1) 90% experience curve model

OPTIONS	Total 5 yrs. profit	Total 5 yrs. inv.	Cash Flow	Max Cap Empl.	ROCE
RETRENCH	1241	50	Pos. cash generated	1465	15-20%
CURRENT PATH	638	440	Neg. thru period	2515	Declining 16-3 %
EXPAND	1792	1760	Neg until last year	6115	Neg until 1976 builds up to 25%
2) 80% experience curve model					
OPTIONS					
RETRENCH	1780	50	Pos cash generated	1465	18% inc to 30%
CURRENT	1528	440	Pos after first year	2515	Inc 13% to 17%
EXPAND	3555	1760	Neg until 4th year of plan	6115	Neg until 1976, rapid Inc to 39%
3) 70% experience curve model					
OPTIONS					
RETRENCH	2333	50	Pos, cash generated	1465	21% inc to 42%
CURRENT	2417	440	Cash gen after 1st yr.	2515	16% inc to 30%
EXPAND	5459	1760	Neg until 4th year	6115	Neg until 1976, rapid Inc to 52%

APPENDIX B

Statistical methods used in testing models, and details of cases in the literature where models have been tested in this way

Index

APPENDIX B

Statistical methods used in testing models, and details of cases in the literature where models have been tested in this way

B.1 Statistical methods used in testing models.

(As also used in later work reported in Chapter Five)

The models to be tested can all be expressed in a linear form:

Log/log	$\text{Log } c = \log a + b_1 \log V_1 + \ldots$
Log/linear	$c = \log a + b_1 \log V_1 + \ldots$
Linear	$c = a + b_1 V_1 + \ldots$
Inverse	$c = a + \frac{b1}{V1} + \frac{b2}{V2} + \ldots$

Where c = unit cost, average price, or other form of dependent variable

V_1, V_2.. are independent variables

a, b_1, b_2.... are the parameters of the model

Thus, the fit of the models to relevant data can be tested using standard linear regression techniques. Basically, the assumption that a model fits a set of variables is used to form a hypothesis about the relationship between the variables, which can then be tested on a sample set of data.

Hypothesis testing and levels of significance

Statistical methods of regression analysis provide procedures which enable a decision to be made on whether the hypothesis should be accepted or rejected, based on the relationship found between the sample set of variables.

If the hypothesis is rejected when it should have been accepted, a Type I error has been made. If, on the other hand, a hypothesis has been accepted when it should have been rejected, a type II error has been made. In either case a wrong decision has occured. Statistical tests are designed to minimise these errors.

In testing a given hypothesis, the level of significance of the test is the maximum probability of incurring a Type I error. This is specified before testing the sample data. Typical levels of significance used in tests are 0.05 or 0.01 (5% or 1%). Since the hypothesis is a statement about the distribution of the variables, the level of significance and the distribution can be used to determine the critical level for some test statistic, s_x say. The test of the hypothesis would then be the following:

> If sample statistic s calculated from the sample data is $< s_x$, accept the hypothesis.
>
> If sample statistic s calculated from the sample data is $> s_x$, reject the hypothesis.

If the level of significance of the test is 5%, the chances of having rejected the hypothesis when it should have been accepted would be 5 in 100.

Tests of hypothesis about the above models

Using a simple linear model to illustrate the general method used,

Let the model be $y_i = a + bx_i + \varepsilon_i \quad i = 1, \ldots n$

where i) x_i are known exactly

ii) $\varepsilon_i \sim IN(0, \sigma^2)$

iii) $\alpha_1 \beta$ are parameters of the model.

Then the null hypothesis (hypothesis to be tested against any other alternative) is that $\beta = 0$, ie there is no linear relationship between variables x and y.

There are two ways of testing this hypothesis, using the T-test and the F-test. Both test whether the sample estimate of β, b, calculated from the sample data, is significantly different from zero.

Now, the sample estimate of β, b is distributed normally with variance $\frac{\sigma^2}{\Sigma(x_i-\bar{x})^2}$

ie $b \sim N\left(\beta, \frac{\sigma^2}{\Sigma(x-\bar{x})^2}\right)$

Sample variance of β can be estimated using sample estimate of σ^2, $\hat{\sigma}^2$, where $\hat{\sigma}^2 = \sum \frac{(yi - \hat{y}i)^2}{(n - 2)}$

Where $\hat{y}i$ is the estimated value of yi for i = 1, ...n.

T-test

The sample statistic

$$t = \frac{b - \beta}{\sqrt{\frac{\hat{\sigma}^2}{\sum (xi - \bar{x})^2}}}$$

is distributed as in the Student's distribution. Test of the null hypothesis, at a level of significance of α_1 would be to compare the sample value of t, assuming $\beta = 0$, with the critical value t_α obtained from tables giving critical values of t_α for varying levels of significance.

F-test

The sample statistic F is used to test whether two different estimates of variance are significantly different from each other.

$$\text{Regression sum of squares} = \sum (\hat{y}i - \bar{y}i)^2 = \sum \left[a + bx_i - (a + b\bar{x})^2 \right]$$

$$= \sum b^2 (xi - \bar{x})^2$$

$$= b^2 \sum (xi - \bar{x})^2$$

It can be shown that the expected value of regression sum of squares is $\sigma^2 + \beta^2 \sum (xi - \bar{x})^2$

The residual sum of squares $= \sum(yi-\bar{y})^2$

and has an expected value of $(n-2)\sigma^2$

Thus, if the null hypothesis, $\beta = 0$, is true, the quantities $b^2 \sum(x-\bar{x})^2$ and $\sum(yi-\bar{y})^2$ are both estimates of σ^2.

Since the F ratio is the ratio of two different estimates of the same variance, the test statistic

$F = \frac{\sum(yi-y\bar{i})^2}{\sum(yi-\bar{y})^2} \times (n-2)$ can be used to test the hypothesis that

$\beta = 0$, against a critical value for F_α, again found from tables of the F distribution.

In fact, the test statistic F is the square of the t statistic:

$$t = \frac{b}{\sqrt{\frac{\hat{\sigma}^2}{\sum(xi-\bar{x})^2}}} \qquad \text{(assuming } \beta = 0\text{)}$$

$$t^2 = \frac{b^2 \sum(xi-\bar{x})^2}{\hat{\sigma}^2} = \sum\frac{(\hat{y}i-\bar{y}i)^2}{\hat{\sigma}^2} \text{ (see above)}$$

$$\hat{\sigma}^2 = \frac{\sum(yi-yi)^2}{n-2}$$

$$\therefore \quad t^2 = \frac{\sum(\hat{y}i-\bar{y}i)^2}{\sum(yi-\bar{y}i)^2} \times (n-2) = F$$

<u>Descriptive measure of goodness of fit</u>

As well as results from the T-test or the F-test, this process also provides a descriptive measure of the goodness of fit of the model to the sample data.

$$\frac{\text{Regression sum of squares}}{\text{Total sum of squares}} = \frac{\sum(\hat{y}i-yi)^2}{\sum(yi-\bar{y})^2}$$

Known as R^2, this ratio expresses the amount of variation in y which can be attributed to variation in the x's, and is frequently given as a percentage.

If $R^2 = 1$ (100%), all variation in y is due to variation in x.

APPENDIX B.2.

Details of cases in which the experience curve and/or similar models have been tested on actual data.

a) Data for airframe production (Alchian, A. 1950)

Data

Direct labour requirements in production of 22 different airframe models.

Source

World War II Basic Data; Airframe Industry, Vol I, AAF Material Command.

Model

$$\text{Log } m = a + b \log N \text{ (experience curve model)}$$

where m = direct labour per pound of airframe

N = Cumulative no of airframes up to and including N^{th}

a and b, parameters, $-1 < b < 0$, $10^a > 0$

As well as testing the validity of the model, Alchian was testing for universal parameters a_o, b_o across all airframe types, and for reliability of predictions from this model. He also tested alternative independent variables of elapsed time and rate of production.

Results

i) Correlations with the above model exceeded 0.9 in 16 cases and 0.8 in the other 6. (Not known if this refers to r or r^2)

ii) The parameters were significantly different for different types of airframe.

iii) Percentage error between predicted and actual direct labour requirements averaged 25%, and was no worse for the industry average curve than for curves for individual airframe types.

iv) The models using time or rate of production as independent variables gave no better fit; the reason put forward for this result was the very high correlations found between each of elapsed time, rate of output, and cumulative output.

Conclusions

Although parameters vary significantly across airframe types, for practical purposes (eg in estimating requirements for contracts) the average curve for the industry will give no greater error than individual models.

b) Data from production of machine tools (Hirsch, W.Z, 1952)

Data

Total machining hours plus total assembly hours, giving total direct labour input of a given product, for seven differing machine tools from one of the largest US machine tool manufacturers, covering the period 1946-1950.

Models

1) $\log y = a + b \log x$ (experience curve model)

2) $y = a + bx$ (linear model)

(y = direct labour requirements per machine)
(x = cumulative lot number a,b parameters of the model)

In preliminary tests on two machines, independent variables lot size and average direct labour plant employment were also included in the model. Lot size was chosen to indicate rate of production since intervals between lots were fairly stable and lot size revealed the frequency of operation on each machine. The average direct labour plant employment was chosen to indicate the overall scale of operation. However, the results indicated that there was no significant relationship between direct labour requirements and either of these variables, at a 5% level of significance.

Results

i) In all cases the experience curve model fitted the data at a 1% level of significance. Values of the correlation coefficient r (adjusted for degrees of freedom) ranged between 0.84 and 0.96.

ii) In one case the linear relationship gave a better fit, increasing the value of r from 0.89 to 0.94.

iii) In the two cases tested, neither lot size nor direct labour plant employment were significantly correlated with direct labour requirement.

iv) If serial correlation was eliminated by using every other observation, results were still significant.

v) An average curve from pooled data was significant at a 4% level.

Conclusions

Empirical estimates of curves can be used for predicting labour requirements and cost, and scheduling of labour, material, and use of equipment.

c) Data from a variety of products (Conway, R.W, and Schultz, J.R., 1959)

Data

Direct labour input and production costs associated with products from 8 different plants from 4 different firms. Complexity of the product varied from extremely complex to relatively simple, and cumulative production from 50 units to 20,000 units.

Models

$\log y_i = a - b \log i$ (experience curve model)

and $y_i = a - bi$ (linear relationship)

where y_i = labour hours required for i^{th} unit

i = production count (ie cumulative output)

a = labour hours required for 1st unit ($a=y_1$)

b = measure of rate of production.

Results

No statistical results given, but examples cited in the text indicated that a rigorous approach had been taken.

Conclusions

Progress in reduction in labour input required exists, for longer periods of time and for a greater variety of products than would have been expected.

The log/log formulation of proper data shows the duration and extent of this progress more clearly than arithmetic plots. Empirical studies indicate that the amount of progress experienced in these industries studied is significant in both economic and planning terms, and in many cases is well-fitted by a log/log plot.

d) Industries requiring investment in heavy equipment (Hirschmann, W.B., 1964)

Data

i) Petroleum refinery units-output capacity in terms of number of days to process 100,000 barrels.

ii) Labour man hours needed for maintenance and shut-downs, and replacement of groups of parts.

Model

i) $\log y = a + b \log x$

y = no of days required to process 100,000 barrels

x = cumulative no of barrels processed

ii) $y = a + b\,x$

y = labour man-hours required for shut down

x = elapsed time

iii) $\log y = a + b \log x$

y = average time per replacement (of group of parts)

x = cumulative number of replacements

Results

No details of statistical analysis, all results only given in terms of graphical plots.

Conclusion

All results suggest a regular decline in the dependent variable.

e) <u>Machine intensive production 'startups'</u>

(Baloff, N., 1966)

<u>Data</u>

28 separate cases of new process and new product 'startups', in 5 companies from 4 different industries. All with varied type of product and process, but all using sophisticated mechanisation, large capital investment, high rates of output, small amounts of direct labour.

<u>Model</u>

Log y = a + b log x

y = index of process productivity, eg input per unit of output.

x = cumulative output of the process.

a,b parameters of the model.

<u>Results</u>

All startups were marked by large regular increases in productivity for some months following the start of manufacture.

Fit of the model was significant at 99.5% (0.5%) level of significance in all cases, with values of r^2 between 0.88 and 0.99.

f) Production startups in musical instruments, items of casual wear, and new automobile models
(Baloff, N., 1971)

Data

i) From six new models of a large musical instrument, startups taking place over 10 years in a single manufacturers plant. (Products large and complex)

ii) Three cases of startups in a distinct 'style line' of casual wear in an apparel manufacturers.

iii) Four startups in assembly of new automobile models, all in one firm, all subassembly and final assembly operations.

Model

$$\log y = a - b \log x$$

where y = index of cost or labour expenditure per unit
x = cumulative output of units.
a,b parameters of model

Results

i) Musical instruments; fit of model significant at a 99% (1%) level in all cases, with values of r all exceeding 0.9. ($r^2 > 0.81$)

ii) Apparel; all significant at 99% (1%), values of r all exceed 0.898. ($r^2 > 0.80$)

iii) New automobile models; all significant at 99%, values of r all exceed 0.86. ($r^2 > 0.73$)

Conclusions

Learning curve can find useful application in a wide spectrum of machine and labour intensive production activities. Can be used for planning, scheduling, and costing.

g) Radar Equipment (Preston, L.E., & Keachie, E.C., 1964)

Data

22 observations for total unit production cost, unit labour cost, and volume of output per production run for the production and assembly of 5 different pieces of radar equipment. The 5 sets of data were reduced to a single series of cost-output observations for the analysis.

Model

i) $\log y = a + b \log x_1 + c \log x_2$

ii) $y = a + b x_1^{-1} + c x_2^{-1}$

iii) $y = a + b \log x_1 + c \log x_2$

where y = unit labour cost or unit total cost

x_1 = lot size (volume of output per production period)

x_2 = cumulative output

Results

In all cases but one, the models fitted the data significantly, with inclusion of both independent variables (cumulative output and lot size) being significant at a level of at least 5%. R^2 varied between 0.88 and 0.90.

In one exception, inclusion of variable x_1 (lot size) in the model (iii) failed to meet significance levels.

Conclusion

Inclusion of both cumulative output and level of output per production period as significant variables in the explanation of the level of unit production costs has important implications for both teaching and research. Some of the evidence previously taken to reflect economies of scale may in fact reflect the accumulation of experience by long established large firms and plants. Thus, available estimates of minimum optimal scales of production may be high.

h) <u>Data on a range of products</u> (Woolley, K., 1972)

<u>Data</u>

Average cost of manufacture of 18 different products from 10 different companies chosen to satisfy the following requirements:

a) The product is manufactured.

b) Products with high discretionary promotion costs are excluded.

c) Products manufactured in conjunction with other very closely related products are excluded.

d) Products which change rapidly in a physical sense are excluded.

Products included chemical film, chemically treated paper, fabricated knitwear, other knitted products, facial tissues, steel product, 2 types of lawnmower, complex electronic tube, electronic sensor, electronic recording instrument etc.

Data for the average cost of manufacture over a whole years period was converted to constant terms using a British GNP for the 3 UK firms, and the US GNP for the remainder.

Periods of data range from 4 to 14 years.

Model

$$\log y = a - b \log X$$

where y = cost of manufacture per unit (in constant terms)

x = cumulative output

a,b parameters of the model.

Results

Values of r^2 ranged from 0.34 to 0.99. In 14/18 of the cases r^2 was over 0.9, and the fit of the model was significant at a 1% level. In 3 of the remaining 4 cases, results improved when joint costs were excluded.

Conclusions

The evidence strongly supported the hypothesis of a log/log relationship between unit cost and cumulative output.

i) Turbine generators, power capacitors, power transformers (Sultan, R.G.M., 1975)

Data

Price data from turbine generator output to establish long term trends, and the more limited amount of cost data to check the trends. Data from power transformers and power capacitors, plant used in the same utilities by the same manufacturers, also used to check results.

Models

i) $\log y = a + b \log x$

ii) $y = a + b \log x$

iii) $y = a + b x$

iv) $y = a + b T$

where y = average value per kilowatt

x = cumulative kilowatt shipments

T = elapsed time

a,b parameters of the model.

Results

Turbine generator data:

Model (i) : $R^2 = 0.35$

(ii) : $R^2 = 0.42$

(iii) : $R^2 = 0.35$

(iv) : $R^2 = 0.42$

Power capacitors: Model (i) gives the best fit ($R^2 = 0.95$)

Power transformers: model (i) gives best fit ($R^2 = 0.49$)

2nd experiment on data for direct cost per kilowatt for turbine generators.

Model

Log/log model including the following independent variables

Cumulative number of kilowatts produced

Average size of a unit (representing product technology)

Rate of utilisation of design capacity.

Technological transfer between competitors (by introducing dummy variables for other firms)

Price index for generator orders received in year T. (represents how busy the firm is)

Results

The independent variables statistically significant in explaining variation in direct cost per kilowatt were the cumulative number of kilowatts produced, average size of a unit, and price index for generator orders (with positive coefficient).

Conclusion

Production experience (represented by cumulative output)and product technology (represented by average size of a unit) are strongly correlated with cost reduction. However, cost cutting procedures are relaxed when backlogs are heavy, the factory is busy and order prices are high.

The data does not support the hypothesis that direct cost per kilowatt is affected by the rate of utilisation of factory capacity or transfer of technology effect.

j) Petrochemical data (Stobaugh, R.B., and Townsend, P.L., 1975)

Data

Prices and other data from 82 petrochemical products produced primarily from petroleum and natural gas. Source of data was the US Tarriff Commission in United States Production and sales of Organic Chemicals. Chemicals included in the study are those for which 1969 sales were S 10 million or more, for which data was reported for at least several years.

As dependent variable, the price is used as a proxy variable for value added by the petrochemical manufacturer, since prices of basic raw materials changed little over the years included in the study.

<u>Model</u>

$$\left[\frac{Pi+r}{Pi}\right] = K\left[\frac{Ni+r}{Ni}\right]^{B_1}\left[\frac{\text{Standard} = e}{\text{non-standard} = 0}\right]^{B_2}\left[\frac{\text{Cum } Qi+r}{\text{Cum } Qi}\right]^{B_3}\left[\frac{Si+r}{Si}\right]^{B_4}$$

where Pi = average price in year i

r = years of interval being considered

Ni = Number of producers in year i

Dummy variable = 0 if product has non-standard specifications

= e if product has standardised specifications (1 in log/log model)

Cum Qi = Cumulative production through year i

Si = average production per producer in year i

$K, \beta 1, \beta 2, \beta 3, \beta 4$ = coefficients determined by regression

(Model transformed by taking logs to linear form)

NB. The independent variables Ni and product standardisation were expected to result in declines in price, experience and production per producer expected to reduce cost through improved technology and operating procedures, and economies of scale.

Results

All four explanatory variables were found to be significant factors causing price declines over intervals of 5 or 7 years, whereas only the number of producers and cumulative production were significant over the shorter intervals of 1 and 3 years. The coefficient of determination was low, indicating a low degree of explanation of price changes. (R^2 = 0.03 for 1 year intervals, 0.27 for 7 year intervals). Also, the constant K was highly significant as a contributory variable, indicating that an important variable was missing. Stobaugh and Townsend speculate that this was probably a time-related factor.

(Significance level of 5% used throughout)

Secondary experiment

The improved fit of the combined model described above over that of the experience curve model was tested for 13 families of products of similar petrochemicals.

Results

In 10/13 cases the combined model gave higher values of R^2, but in only 3 of these cases was the improvement significant at 95% level (5%). This result was particularily true in the smaller, more homogeneous families.

Conclusion

Competition, product standardisation, experience and static scale are all significant factors in the decline of petrochemical prices, and act in the expected directions. Experience and the combined effect of unidentified time-related variables generally have a larger effect than the number of producers, product standardisation or static scale.

Use of smaller and more homogeneous groups leads to a better explanatory model.

APPENDIX B.3

References for use of the experience or learning curve model in production planning, costing etc.

1) Production scheduling and costing of contracts

White, J.M., 1961 Uses of Learning Curve Theory in setting Management Goals. Journal of Industrial Engineering Vol 12.

Williams, P.F., 1961, The Application of Manufacturing Improvement Curves in Multiproduct Industries. Journal of Industrial Engineering, March/April 1961.

Baloff, N., 1966 Startups in Machine Intensive production systems. Journal of Industrial Engineering, 17, 25.

Cochran, E.B., 1960, New concepts of the learning curve. Journal of Industrial Engineering Jul/Aug 1960.

2) The setting of prices, planning of delivery schedules, forecasting of requirement for capital and labour.

Andrews, F.J., 1954, The learning curve as a production tool, Harvard Business Review, January/February 1954.

3) Evaluation of new product projects, make or buy decisions, comparison of suppliers' prices.

Conway, R.W., and Schultz, A., 1959, The Manufacturing Progress Function, Journal of Industrial Engineering, January/February 1959.

4) Setting of standard costs for accounting purposes.

Said, K.E., Management Applications of learning Management accounting (UK), Sept. 1975.

Hallbauer, R.C., 1975, Statistics, Management Science, and Standard cost. Cost and Management (Canada) May/June 1975.

Leininger, W.E., and Spangler, R., 1976, Learning Curves and Setting Standard Costs. Cost and Management (Canada) Nov/Dec 1976.

5. Personnel and manpower planning

Causey, D.Y., 1977, Personnel Programming Managerial Planning (USA), Jan/Feb 1977.

Gibbons, T.T., and Devlin, L., 1976, A model for manpower utilisation. Industrial Engineering (USA) Aug 1976.

Gordon, R.L., and Lamb, J.C., 1977. EDP Manpower planning. Data Mation (USA), June 1977.

6. Price-setting as a marketing tool.

Jain, S., 1975, Translating Experience into Growth. Managerial Planning (USA) Mar/Apr 1975

Appendix C

Analyses to test the fit of experience curve models to data from BOC Arc Equipment and the UK arc welding equipment industry (as represented by members of BEAMA)

Index

Appendix C

Analyses to test the fit of experience curve models to data from BOC Arc Equipment and the UK Arc Welding Equipment Industry (as represented by members of BEAMA).

1. Boc Arc Equipment - data for one product line.

This investigation was designed partly to survey the availability and quality of data for individual product lines, and partly to find out whether individual products had had a reduction in unit cost which could be modelled by an experience curve.

1.1 The product line

This consisted of individual models ADR 200 and 300, together with models of the same specification made for other equipment manufacturers (the HDA 300, RAC 300 and ADS 300), plus the AC/DC 375 which eventually replaced both the ADR 200 and 300. The ADR was a very basic TIG rectifier, the design of which remained virtually unchanged over the period in question, 1966-77.

1.2 Data

Available data and sources were as follows:-

a) Volume of output in units (production programs)

b) Selling price to BOC, 1966-72 (delivery notes),
N.B. at that time rectifiers were manufactured by Hirst Welding Rectifiers (HWR), later taken over by BOC (Thesis 2.3.2).

c) Standard cost 1973-77 (record cards). Over this period the transfer price from HWR to BOC was supposed to be:

1973/4 to 1975/6	Standard cost x 1.3
1976/77	Standard cost x 1.4

1.3 Method

a) Data was adjusted for inflation. Two indices were used and the results were compared -

Index (1), Index of retail prices for the output of all manufactured products, Home Sales

(2) Price Index for Capital expenditure on plant and machinery for Total Manufacturing Industries.

b) Selling price pre 1972/73 was not compatible with transfer price post 1972/73. In order to adjust for the inconsistency, pre 1972/73 figures were multiplied by the ratio

$$\frac{\text{Transfer price 1972/73}}{\text{Selling price 1971/72}}$$

c) When two models are being produced concurrently, a weighted average of selling price or transfer price was calculated.

d) Adjusted data was then fitted by the model $\log c = a - b \log V$

where c = selling price 1966/67 - 1972/73,

transfer price 1973/74 - 1976/77

V = Cumulative output (cumulative number of units produced since 1966).

A test of the relationship between log c and log V is obtained by testing the hypothesis $b = o$, using the techniques of regression described in Appendix B.1.

Some data was also tested using the time trend model

$c = a + bT$ where c = selling price/transfer price

T = elapsed time in years

a,b are parameters of the model.

Table C.1.1 Data for one product line

a) Numbers produced and cumulative output

Model	1966/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	Cum. Total
		Numbers produced (Units)										
ADR 200	62	60	89	30	75	85	51	32	-	-	-	484
ADR 300	100	202	185	179	174	240	265	369	464	139	38	2355
HDA 300	-	-	-	13	7	9	15	8	-	-	-	52
RAC 300	-	-	6	5	9	4	5	21	13	30	38	131
ADS 300	-	-	-	3	10	10	10	10	10	18	15	86
AC/DC 375	-	-	-	-	-	-	-	-	-	217	302	519
Total	162	262	280	230	275	348	346	440	487	404	393	3627
Cumulative output	162	424	704	934	1209	1557	1903	2343	2830	3234	3627	

b) Selling price and transfer price (£)

	1966/7	67/8	68/9	69/70	70/1	71/2	72/3	73/4	74/5	75/6	76/7
ADR 200 Selling price	331.9	345.8	350.25	374.25	374.25	375.00	263.07				
ADR 300 (+others) Selling price	ave 379.00	ave 384.12	ave 391.25	ave 402.12	ave 424.05	425.00					
transfer price							271.95	378.27	481.81	611.77	786.90
AC/DC 375 Transfer price										(Est) 940.00	945.30
Weighted Average	361.0	375.2	377.1	397.5	410.4	412.8	270.6	378.3	481.8	788.1	908.6
Deflating Index (1)	86.5	89.9	93.4	100	109	114.8	123.2	152.0	188.7	218.6	255.3
Deflating Index (2)	85.1	86.1	88.7	97.3	108.1	115.4	124.5	145.9	188.2	228.0	259.7
Deflated Price (1)	417.3	417.4	403.7	397.5	376.5	359.6	219.8	248.9	255.3	360.5	355.9
Deflated Price (2)	424.2	435.8	425.1	408.5	379.7	357.7	217.4	257.3	256.0	345.7	349.9

Table C.1.1. continued

c) Adjustment to make figures compatible pre and post 1972/73.

Make selling price for 1971/72 the same as transfer price 1972/73, and adjust previous figures by multiplying by

$$\frac{\text{Transfer price 1972/73}}{\text{Selling price 1971/72}} = \frac{219.67}{359.6} = .6109 \text{ for prices deflated using Index (1)}$$

$$= \frac{217.38}{357.7} = .6077 \text{ for prices deflated using Index (2)}$$

A third version makes the adjustment before deflating the figures, in which case $\frac{\text{Transfer price 1972/73}}{\text{Selling price 1971/72}} = \frac{270.64}{412.78} = .6556$

Average price is then deflated using Index (1).

	1966/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Adjusted figures (£)											
Deflated price using Index (1)	254.9	255.0	246.6	242.8	230.0	219.7	219.7	248.9	255.3	360.5	355.9
Deflated price using Index (2)	257.8	264.8	258.3	248.2	230.7	217.4	217.4	259.3	256.0	345.7	349.9
Weighted price adjusted before deflation	236.7	240.0	247.2	260.6	269.1	270.6	270.6	378.3	481.8	788.1	908.6
Deflated using Index (1)	273.6	273.7	264.7	260.6	246.9	235.7	219.7	248.9	255.3	360.5	355.9
Weighted average selling price (unadjusted) (Deflated using Index (1))	417.3	417.4	403.7	397.5	376.5	359.6					
Transfer price of ADR 300, deflated using Index (1)							220.7	248.9	255.3	279.9	308.2

1.4 Results

a) Fit of experience curve model to data for average selling price/transfer price, deflated and then adjusted

Using index (1), r = 0.28, F = 0.78, not significant at 5% level

Using index (2) r = 0.18 F = 0.55, not significant at 5% level.

b) Fit of experience curve model to data for average selling price/transfer price, adjusted and then deflated

Using index (1) r = 0.22, F = 0.68, not significant at a 5% level.

c) Testing of data as in (a), from 1966/67 to 1974/75 only (deflated using index (1)).

r = -0.06, F = 0.23, not significant at a 5% level.

d) Fit of experience curve model to data adjusted as in (b), for 1966/67 to 1974/75 only.

r = -0.42, F = 1.70, not significant at a 5% level.

e) Fit of experience curve model to weighted average selling price 1966/67 to 1971/72, deflated using index (1),

r = -0.85, F = 10.56, significant at the 5% level.

Best fitting model $\log c = 2.77 - 0.061 \log V$

Experience curve 'slope' = 95.8%.

f) Fit of time trend model to data as in (e),

r = -0.96, F = 53.2, significant at 1% level

Best fitting model: $c = 437.08 - 11.93V$

1.5 Conclusions

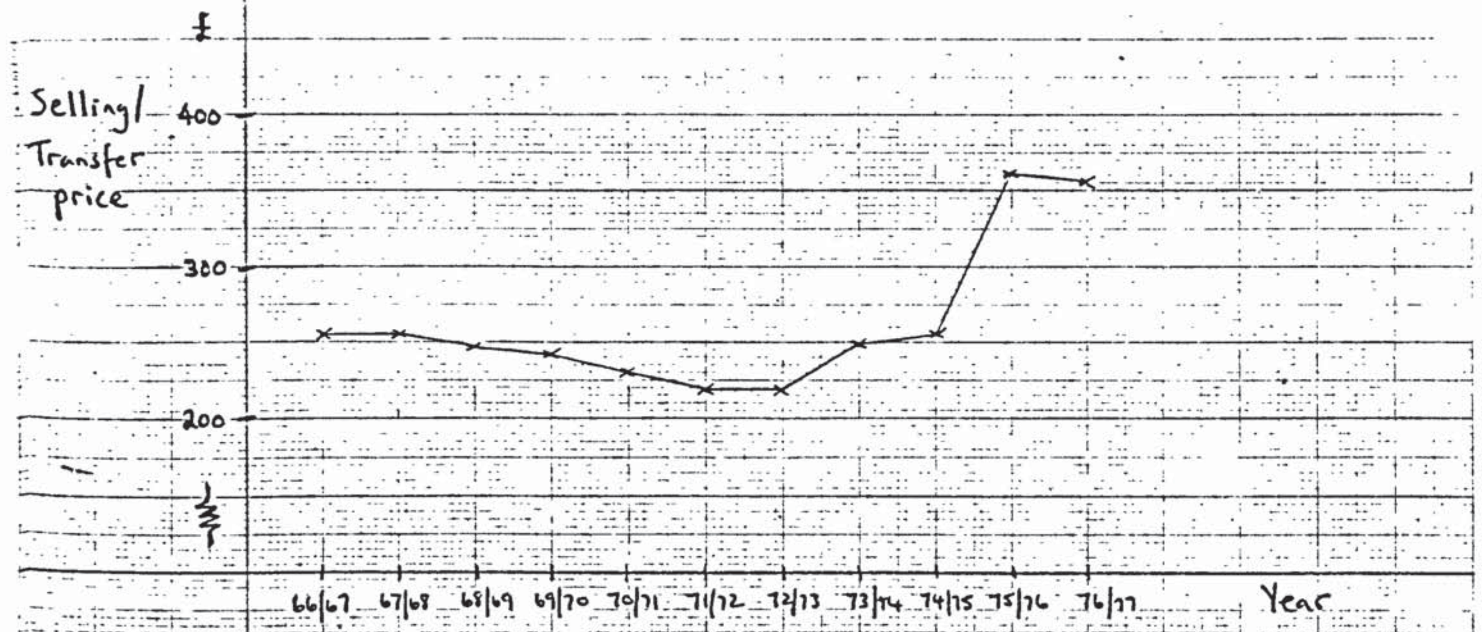
a) Due to anomalies in the data, particularly the lack of compatibility of data between periods pre- and post 1972/73, conclusions cannot validly be drawn concerning the fit of the experience curve model to this data.

b) The selling price, deflated by either index, shows an overall decline over the period 1966/67 to 1971/72, whereas the weighted average transfer price (deflated) rises over the period 1972/73 to 1976/77, even if data for the more costly AC/DC 375 is omitted from the analysis (Graph C.1).

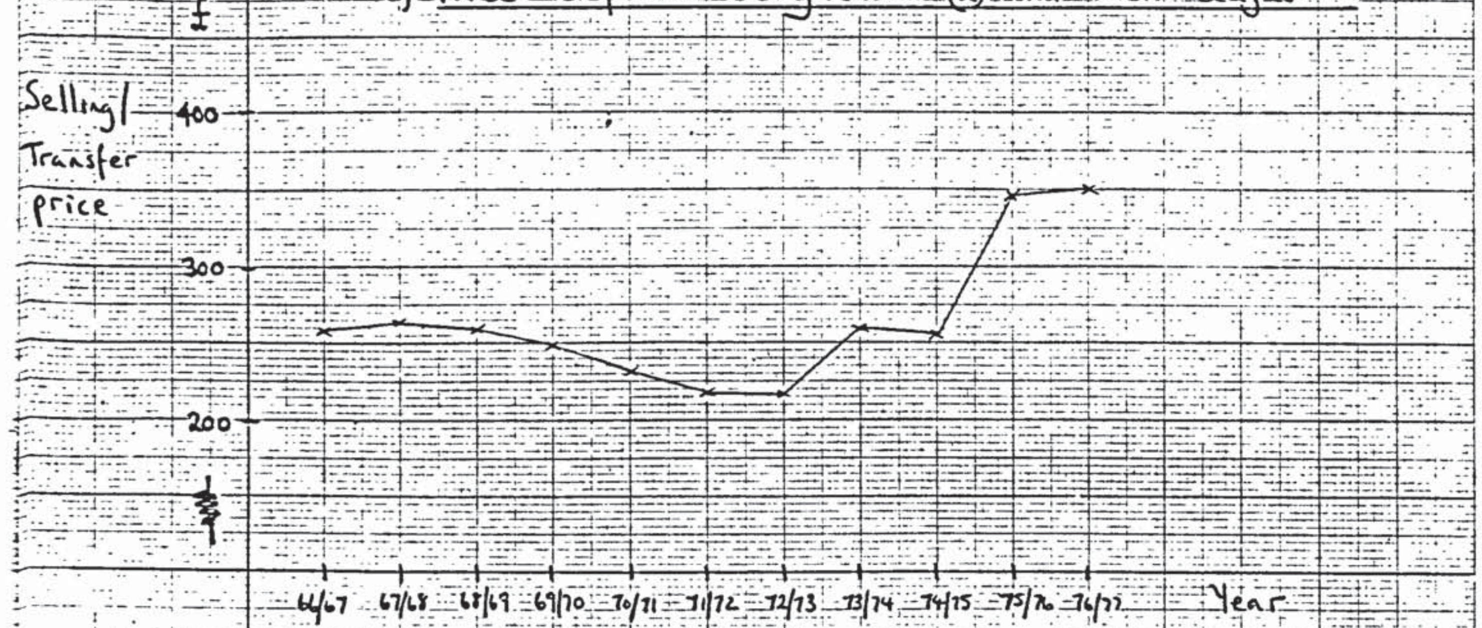
c) Selling price 1966/67 to 1971/72 is fitted by an experience curve model, with the fit of the model being significant at a 5% level. However, a trend line over time gives a better fit and higher levels of significance.

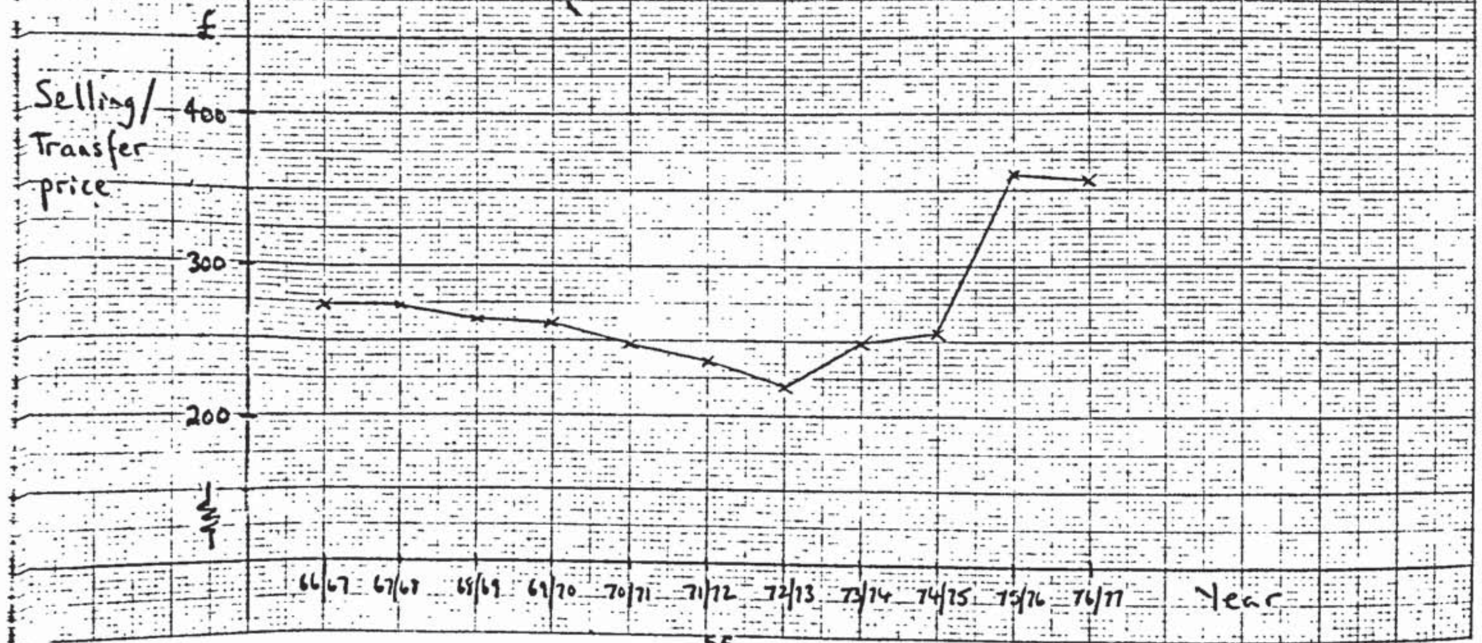
Graph C.1 BCC ARC EQUIPMENT ; Price Behaviour for one product line 1966-77

a) Price deflated using index (1) and then adjusted



b) Price deflated using index (2) and then adjusted





2. Testing the fit of experience curve models to data from BEAMA (The British Electrical and Allied Manufacturers Association).

2.1 Data and methods of analysis

2.1.1 Raw Data (Table 2.2)

Details of value and volume of sales of rectifiers both UK and export, are submitted by BOC to BEAMA quarterly. BEAMA aggregate data from all subscribers and supply each with the quarterly totals.

Firms contributing to BEAMA (Arc Welding Equipment Section)

1964	1977
Associated Electrical Industry Ltd	BKB Electric Motors Ltd
BOC Ltd	BOC Ltd
English Electric Arc Welding Co.Ltd	ESAB Ltd
ESAB Ltd	GKN Lincoln Electric Ltd
General Electric Company Ltd	Max Arc Ltd
Lincoln Electric Company Ltd	Murex Welding Processes
Macfarlane Engineering Company Ltd	Philips Electric Arc Welding Limited
Murex Welding Processes Ltd	
Philips Welding Limited	Rockweld Limited
A. Reynolds & Co. Ltd	Rowen-Arc Ltd
Rockweld Ltd	Union Carbide UK Ltd
Rowen-Arc Ltd (Division of Rubery Owen & Co. Ltd)	
Triangle Products Ltd	

Data for all rectifiers was available from 1962 onwards, with division into MIG and TIG categories from 1972 onwards.

BOC AE pick their totals up from computer tabulations produced from invoiced sales especially for this purpose. UK volume and value of sales are taken from the computer tabulations produced by NAC, WP/SA R.25 (UK Sales by BEAMA classification). Export sales are taken from a computer tabulation produced in-house as part of reporting invoiced sales. (Report No.6, Sales by BEAMA classification).

2.1.2 Method

a) Quarterly data was summed over each year ending in September, in order to tie in with the financial year of BOC Arc Equipment.

b) Average price of a rectifier was calculated using

$$\frac{\text{Annual total value of sales}}{\text{Annual total volume of sales}}$$

The resulting price was then deflated using the index of retail prices for the output of all manufactured products, Home Sales. (Index (1) from part 1 of Appendix C).

c) Cumulative output by 1963 was estimated using the following method. The average compound growth rate was calculated for the period for which data was available (1963-77).

This was then extrapolated backwards from 1963, and the sum of the resulting series formed the estimate of cumulative output for 1963, i.e.

Let Cn be the volume of output in year n, and S be cumulative output produced by the end of year n.

i.e. $Sn = Cn + Cn{-}1 + Cn{-}2 + \cdots + C{-}\infty$

Assume a constant compound growth rate r $(r > o)$

Then $Cn{-}1\ (1+r) = Cn$

$Cn{-}2\ (1+r)^2 = Cn$
etc.

i.e. $Sn = Cn\left(1 + (1+r)^{-1} + (1+r)^{-2} + \ldots + (1+r)^{-\infty}\right)$

$$= \sum_{m=o}^{\infty} Cn\ (1+r)^{-m}$$

$$= \sum_{m=o}^{\infty} Cn\left(\frac{1}{1+r}\right)^{m}$$

If $r > o$, $\frac{1}{1+r} < 1$ and hence the series is convergent and Sn exists.

S is a geometric series with ratio $\frac{1}{1+r}$

Hence $Sn = \dfrac{Cn}{1 - \frac{1}{1+r}}$

i) Calculating Sn for the year 1963 for volume data aggregated from BEAMA subscribers.

Using sales volume data 1963–77, use linear regression to obtain the best straight line through the data:

$y = 1043.99 + 334.74\,x \quad (c = 0.92,\ F = 75.4)$

where y = volume of output

$x = 1$ for 1963 ... $x = 15$ for 1977

This gives calculated values $y_{63} = 1378.73$, $y_{77} = 6065.13$.

Average compound growth rate (used as estimate of r) is then given by

$$\sqrt[14]{\frac{6065.13}{1378.73}} - 1$$

$$= .1116 \text{ or } 11.16\%$$

The calculated volume y_{63} was also used in estimating S(n), as it was hoped that this would provide a more representative estimate of cumulative output than would be obtained from the true output in any particular year.

$$\text{i.e. } S(n) = \frac{1378.7}{1 - \dfrac{1}{1 + 0.1116}} = 13733$$

ii) Calculations for BOC Arc Equipment.

Using linear regression, best straight line through volume data for 1963–77 was given by

$y = 585.63 + 134.87\,x \quad (c = 0.85,\ F = 33.3)$

Calculated values $y_{63} = 720.50$, $y_{77} = 2608.68$

∴ Average compound growth rate r given by

$$\sqrt[14]{\frac{2608.68}{720.50}} - 1 = 0.09626 \text{ or } 9.63\% \text{ p.a.}$$

∴ Estimated cumulative output by end of 1963 given by

$$S = \frac{720.50}{1 - \frac{1}{1.09626}} = 8205$$

iii) <u>Cumulative output for MIG & TIG rectifiers, separately.</u>

Separate cumulative output for MIG and TIG rectifiers for the year 1971/72, when data starts, is calculated from the estimated total for that year, using the average proportion which MIG forms of total output.

<u>Aggregated data from UK Companies</u>

Average proportion MIG: Total output (by volume) = .730

Proportion of cumulative output 1971/72 = .730 x 40596
= 29636

TIG: Cumulative output = 10960.

<u>BOC Arc Equipment data</u>

Average proportion MIG: Total output (by volume) = .624

Proportion of cumulative output 1971/72 = .624 x 20273
= 12650

TIG: Cumulative output = 7623

iv) Check on sensitivity of estimation of cumulative output

Figures actually used;

Cumulative output of aggregated company data at end of 1962/63 estimated to be 13733 (see (i)).

This exercise consists of a rough estimation of the slope of the experience curve obtained if cumulative output is different.

The errors range from 50% to 150% of the original estimate for cumulative output, although this estimate is more likely to be overstated, since it assumes an infinite history of production.

Method

Average deflated price at beginning and end of period taken from original experience curve equation for aggregated company data 1963-77.

i.e. $y = 3.958 - .302\,x$ (Table 2.7)

which gives deflated price 1963 = 509.51

deflated price 1977 = 313.07

Using ratio form of experience curve

i.e. $$\frac{p_i}{p_j} = \left(\frac{V_j}{V_i}\right)^b$$

where p_i = average deflated price in year i

V_i = cumulative output in year i

b = parameter of model

Obtain $$\frac{p_{77}}{p_{63}} = \frac{313.07}{509.51} = .6144$$

For each Vi, Vj, b is then calculated from

$$b = \frac{\log \frac{p77}{p63}}{\log \frac{V63}{V77}} = \frac{\log .6144}{\log \frac{V63}{V77}} = \frac{-0.2115}{\log \frac{V63}{V77}}$$

Slope of the curve is then obtained using equation

$$\text{Slope} = \frac{1}{2b}$$ (see 3.2.1.)

Table 2.1

Estimates of different slopes of experience curve obtained from differing estimates of cumulative output. (Rough approximation)

	V_{63}	V_{77}	$\frac{V_{63}}{V_{77}}$	$\log \frac{V_{63}}{V_{77}}$	b	Slope
Original Est.	13733	68777	0.1997	-0.6997	0.3024	81.1%
90% "	12360	67404	0.1834	-0.7367	0.2872	81.9%
80% "	10986	66030	0.1664	-0.7789	0.2716	82.8%
70% "	9613	64657	0.1487	-0.8278	0.2556	83.8%
50% "	6866	61910	0.1109	-0.9551	0.2215	85.8%
110% "	15106	70150	0.2153	-0.6669	0.3172	80.3%
120% "	16480	71524	0.2304	-0.6375	0.3318	79.4%
130% "	17853	72897	0.2449	-0.6110	0.3462	78.7%
150% "	20600	75644	0.2723	-0.5649	0.3745	77.1%

Results

Errors of $\pm$ 30% in estimating cumulative output produced differences in estimated slope of experience curve of $\pm$ 2.7%.

If the error is as much as $\pm$ 50%, error in estimated slope of experience curve will be up to $\pm$ 4.7%.

2.1.3 Model and Analyses

The experience curve model

$c = aV^{-b}$ where c is average price of a rectifier (deflated)

V is cumulative output

a,b are parameters of the model

was tested on data for the following.

i) Rectifiers sold by BOC AE, 1963-77

ii) Aggregated data from subscribing companies, all rectifiers sold, 1963-77 (15 readings)

iii) BOC AE data, MIG rectifiers only, 1972-77 (6 readings)

iv) Aggregated company data, MIG rectifiers only, 1972-77 (6 readings)

v) BOC AE data, TIG rectifiers only, 1972-77 (6 readings)

vi) Aggregated company data, TIG rectifiers only, 1972-77 (6 readings)

In addition to tests of the fit of the experience curve model to the above data, the volume of sales for BOC AE and aggregated company data were used to calculate BOC's market share by volume, and this was tested for any significant trend over the period, again using techniques of linear regression.

In order to be able to compare movement in average price of a rectifier sold by BOC AE, and that obtained from aggregated data, both were plotted on a linear scale against elapsed time (Graph 2.9).

2.2 Results (See Table 2.7 and Graphs)

a) Data for the average price of all rectifiers from BOC AE and aggregated company data, 1963-77, supports the assumption of an underlying experience curve model, at levels of significance of 0.1%. The fit of the model to aggregated company data (R^2 = 79%) is better than that for BOC AE data (R^2 = 59%), as may be seen from the graphs (2.1 & 2.2).

b) Taking data for MIG and TIG rectifiers alone, 1972-77, aggregated company data supports the assumption of an underlying experience curve model for average price, at a 1.0% level of significance. Average price for both MIG and TIG rectifiers have declined steadily over this period, and the fit of the model is good, with R^2 of 88% and 90% respectively. (See graphs 2.3 and 2.5).

c) Separate data for MIG and TIG rectifiers from BOC AE, 1972-77 does not support the assumption of an underlying experience curve model for average price, at a 5% level of significance. The graph shows that average price of a BOC MIG rectifier has increased over this period (Graph 2.4), whereas average price of a TIG rectifier declined from 1972-74 and has risen steadily ever since.

d) The average price of a BOC rectifier (MIG & TIG) appears to have declined at the same overall rate as the aggregated company average; estimated slope of the experience curve model for BOC prices was 82.4%, and that for aggregated data was 81%.

However, it can be seen from the graph (Graph 2.9) that, since 1973/74, BOC AE average price has risen, whereas aggregated company average price continued to decline.

e) Annual output volumes of BOC AE and aggregated company data appear to have risen and fallen at the same time as each other, indicating the underlying trade cycle. (See Graph 2.8). There was no significant trend in market share estimated by the proportion by volume which BOC output formed of the total; average share was 45% over the period. Average compound growth rate for the UK market over the period 1963-77, as indicated by volume growth in aggregated company data, was 11.1% p.a. (BOC AE 9.6% p.a.).

Table 2.2 Data used in testing of models and examination of average price behaviour for BOC Arc Equipment and aggregated UK companies (Raw data from BEAMA).

Output volumes, cumulative output and deflated price for BOC Arc Equipment and aggregated data from UK companies.

Year 19..	Index*	Aggregated Industry data				BOC AE data			
		Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £	Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £
62/63	78.0	1315	395.8	13733	507.4	610	385.5	8205	494.2
63/64	80.3	2153	395.6	15886	492.7	908	355.4	9113	442.6
64/65	83.3	2620	344.6	18506	413.7	1225	313.9	10338	376.8
65/66	85.6	3010	337.8	21516	394.6	1464	295.9	11802	345.7
66/67	86.5	2171	369.5	23687	427.2	878	357.0	12680	412.7
67/68	89.9	2633	402.0	26320	447.1	992	398.6	13672	443.4
68/69	93.4	3541	410.7	29861	439.8	1707	408.1	15379	436.9
69/70	100	4030	441.9	33891	441.9	1729	412.1	17108	412.1
70/71	109	2800	465.45	36691	427.0	1095	455.0	18203	417.4
71/72	114.8	3905	429.0	40596	373.7	2070	375.7	20273	327.3
72/73	123.2	5782	445.4	46378	361.6	2820	383.2	23093	311.0
73/74	152.0	5534	499.6	51912	328.7	2540	464.1	25633	305.3
74/75	188.7	4880	614.3	56792	325.5	2313	620.0	27946	328.6
75/76	218.6	5256	663.8	62048	303.7	2438	674.5	30384	308.6
76/77	255.3	6729	734.5	68777	287.7	2660	851.8	33044	333.7

* Index is retail price index of the output of all Manufactured products, Home Sales, 1970 = 100.

Industry average price compared with index

In order to compare, convert industry average price into a price index (1970 = 100), by taking

$$\frac{\text{average price for each year}}{\text{average price for 1969/70}}$$

Table 2.3

1962/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
.90	.89	.78	.76	.77	.91	.93	100	1.05	.97	1.01	1.13	1.39	1.50	1.66

BOC Arc Equipment market share by volume (%)

Table 2.4

1962/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
46.4	42.2	46.8	48.6	40.4	37.7	48.2	42.9	39.1	53.0	48.8	45.9	47.4	46.4	39.5

Data for MIG rectifiers, separately

Table 2.5

Year 19..	Index*	Aggregated Industry Data				BOC AE data			
		Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £	Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £
71/72	114.8	2985	378.2	29636	329.4	1414	302.9	12650	263.8
72/73	123.2	4499	415.2	34135	337.0	1892	336.3	14542	273.0
73/74	152.0	4228	458.2	38363	301.4	1588	431.4	16130	283.8
74/75	188.7	3333	549.9	41696	291.4	1241	567.1	17371	300.5
75/76	218.6	3692	574.9	45388	263.0	1511	594.8	18882	272.1
76/77	255.3	4530	663.8	49918	260.0	1628	767.2	20510	300.5

e) Data for TIG rectifiers, separately

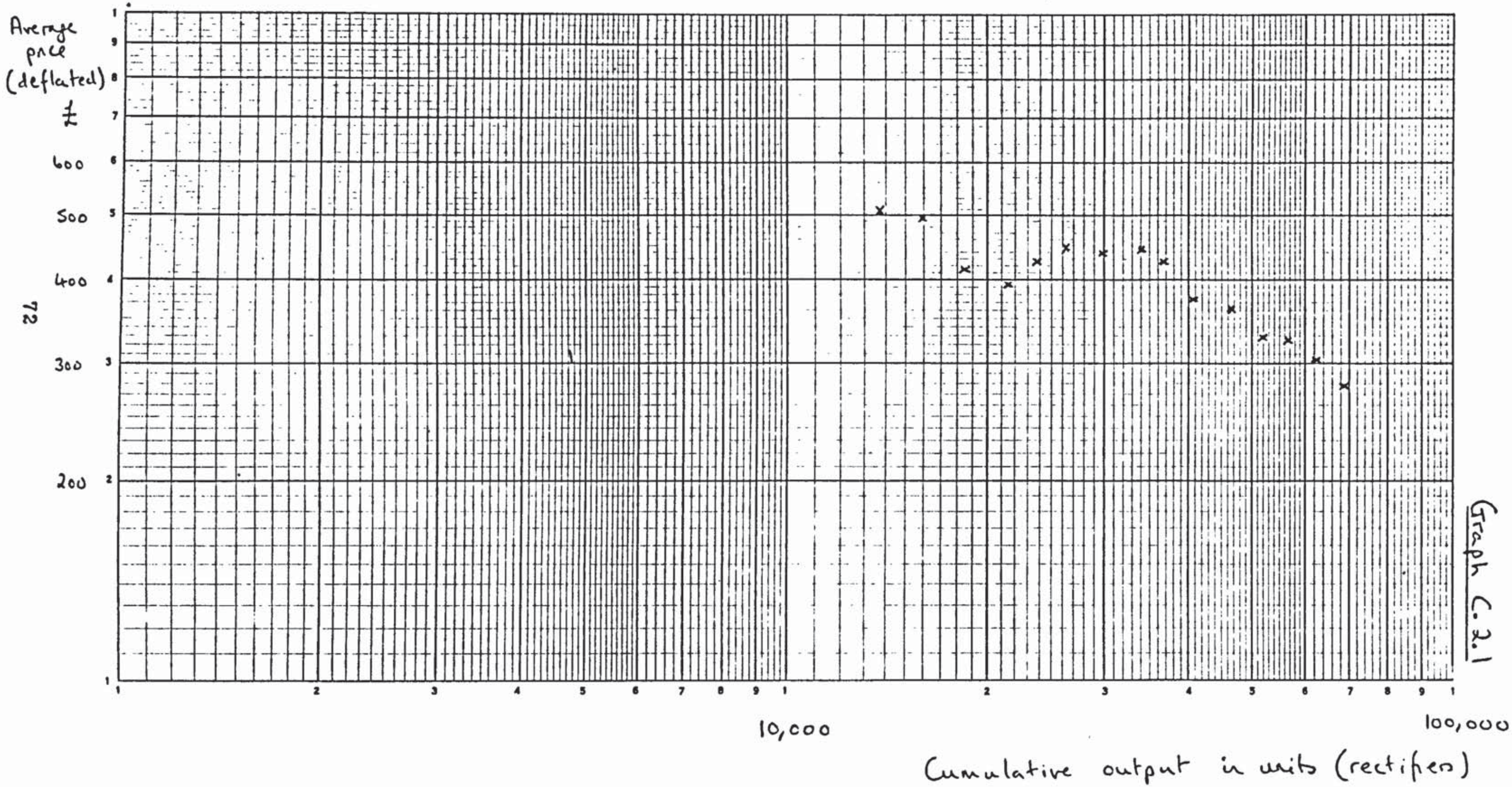
Table 2.6

Year 19..	Index	Aggregated Industry data				BOC AE data			
		Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £	Volume Units	Ave. Price £	Cum. Output Units	Deflated Price £
71/72	114.8	920	592.7	10960	516.2	656	532.7	7623	464.0
72/73	123.2	1283	551.8	12243	447.9	928	478.6	8551	388.5
73/74	152.0	1306	629.0	13549	413.8	952	518.4	9503	341.1
74/75	188.7	1547	753.2	15096	399.2	1072	681.3	10575	361.0
75/76	218.6	1564	874.2	16660	399.9	727	1026.0	11302	469.3
76/77	255.3	2199	880.0	18859	344.7	1035	982.4	12337	384.8

Table 2.7 Results obtained from fitting the experience curve model to each set of data described in 2.1.3.

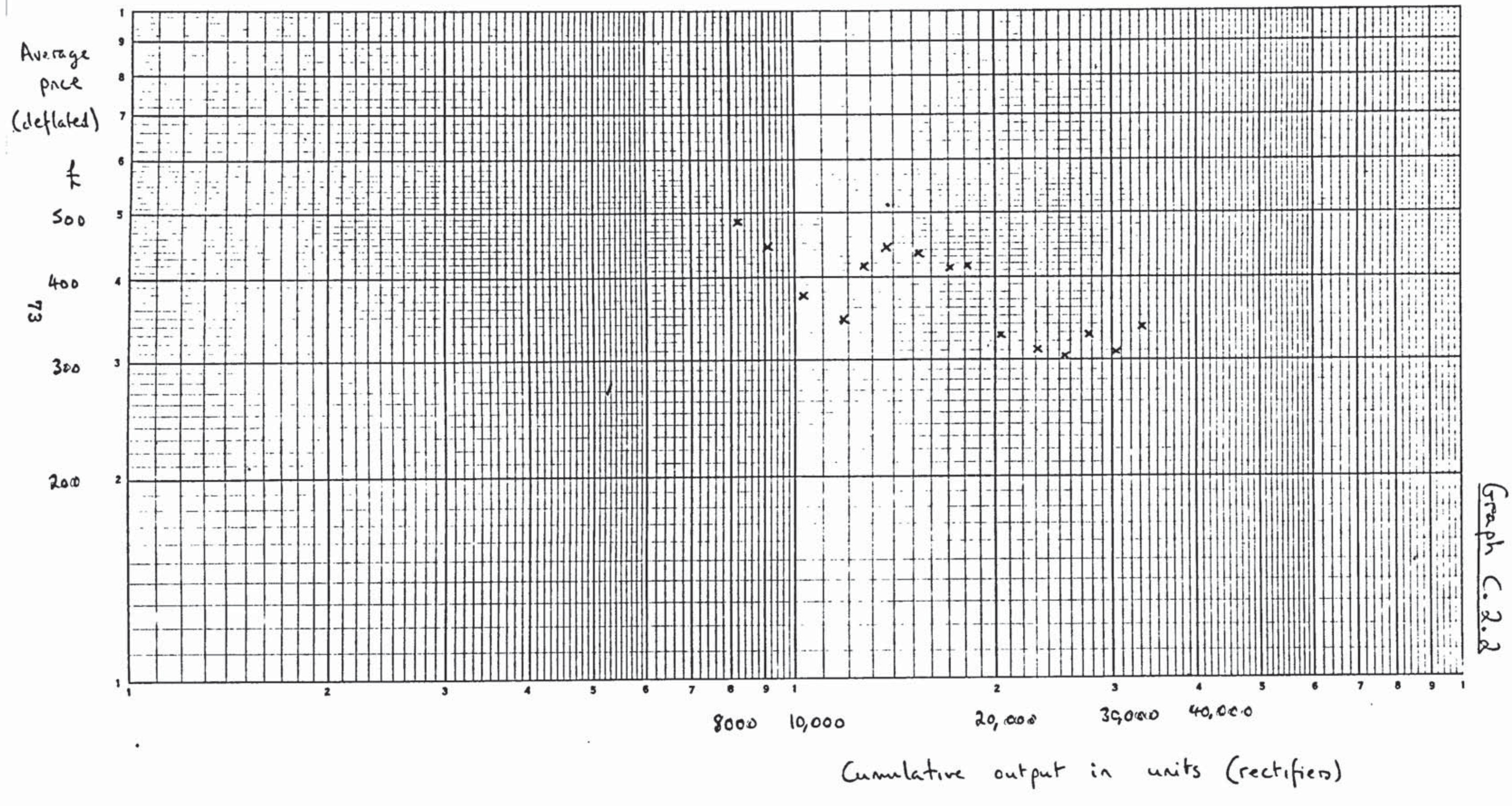
	Dependent Variable	Time Period	Equation	R^2	F	Sig. Level	Exp. curve slope
i)	BOC AE average price, all rectifiers	1963-77	y=3.758 - .2800x	0.59	19.4	0.1%	82.4%
ii)	Aggregated company data, all rectifiers	1963-77	y=3.958 - .3023x	0.79	48.3	0.1%	81.1%
iii)	BOC AE data, average price, MIG rectifiers	1972-77	y=2.200 + .0037x	0.48	3.7	not sig. at 5%	-
iv)	Aggregated company data, MIG rectifiers only	1972-77	y=4.9381 - .5371x	0.88	30.3	1.0%	68.9%
v)	BOC AE data, average price, TIG rectifiers only	1972-77	y=4.490 - .0048x	0.02	.101	not sig. at 5%	-
vi)	Aggregated company data, average price, TIG rectifiers only	1972-77	y=5.2746 - .6387x	0.90	40.1	1.0%	64.2%

C.2.1 Aggregated data from BEAMA subscribers; average price of a rectifier declines 1963-77

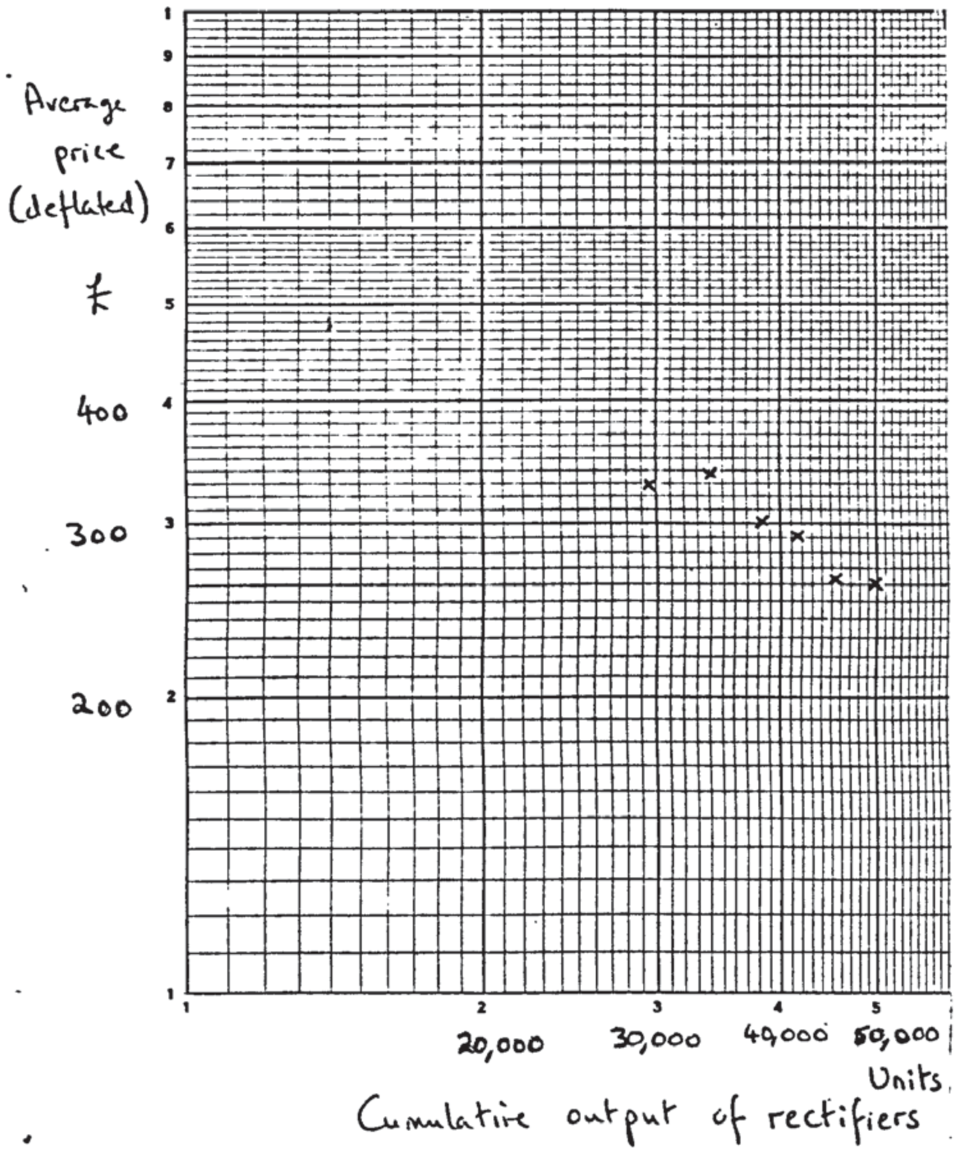


Chartwell Graph Data Ref. 5912 Log 1 Cycle x 2 Cycles

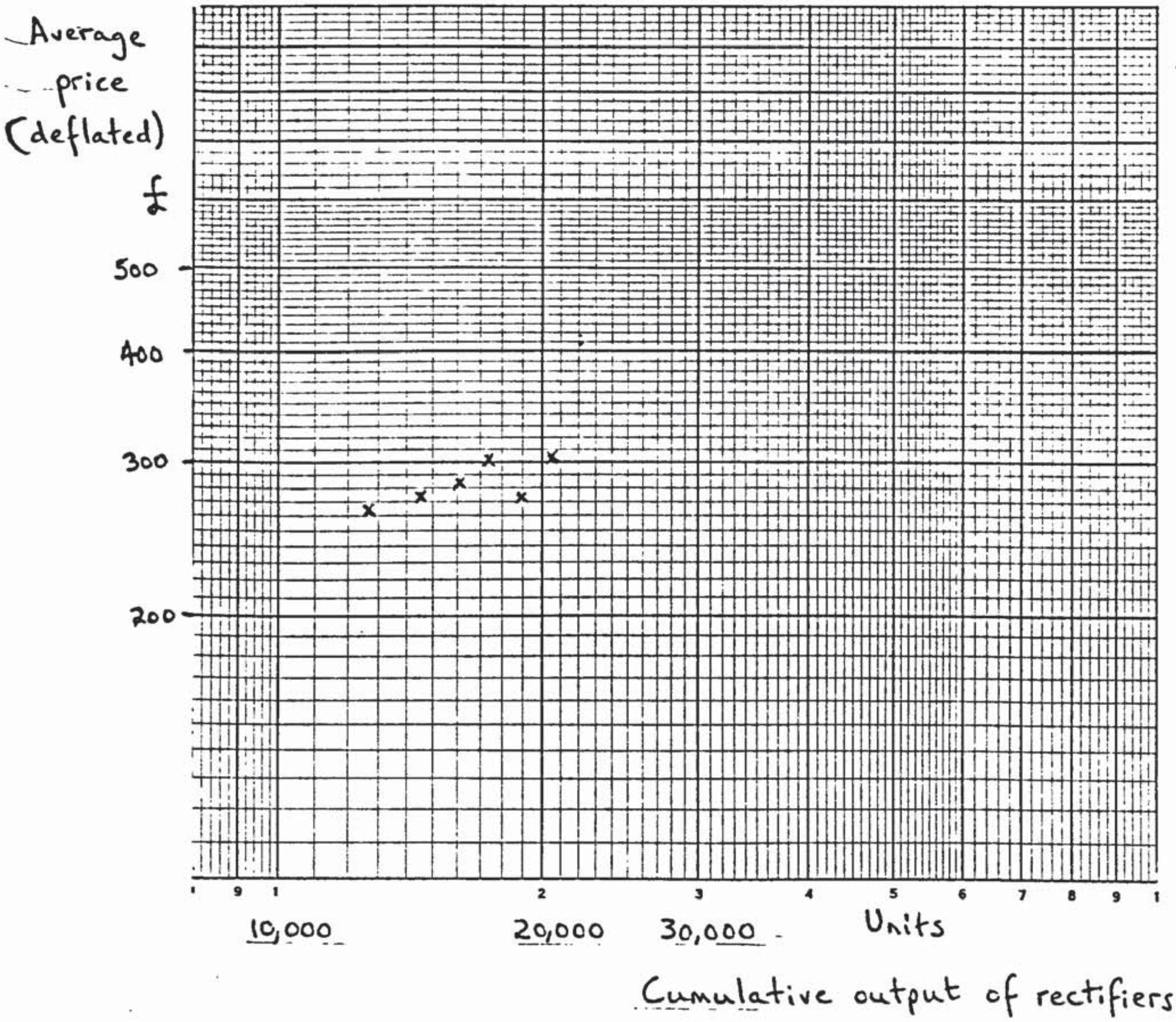
C.2.2 BOC AE (BEAMA data): average price of a rectifier shows an overall decline over the period 1963-77



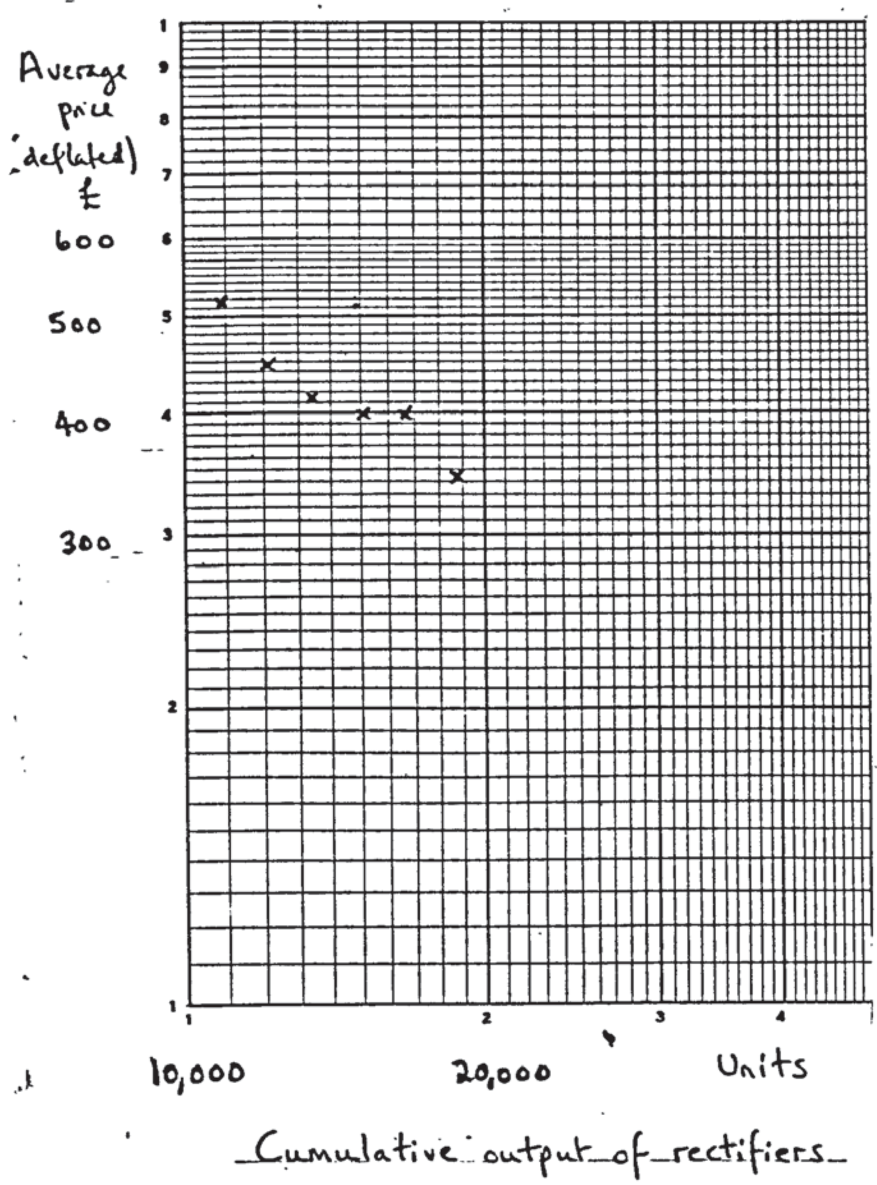
Graph 2.3 Aggregated company data (BEAMA); average price of MIG rectifiers declines 1972 77



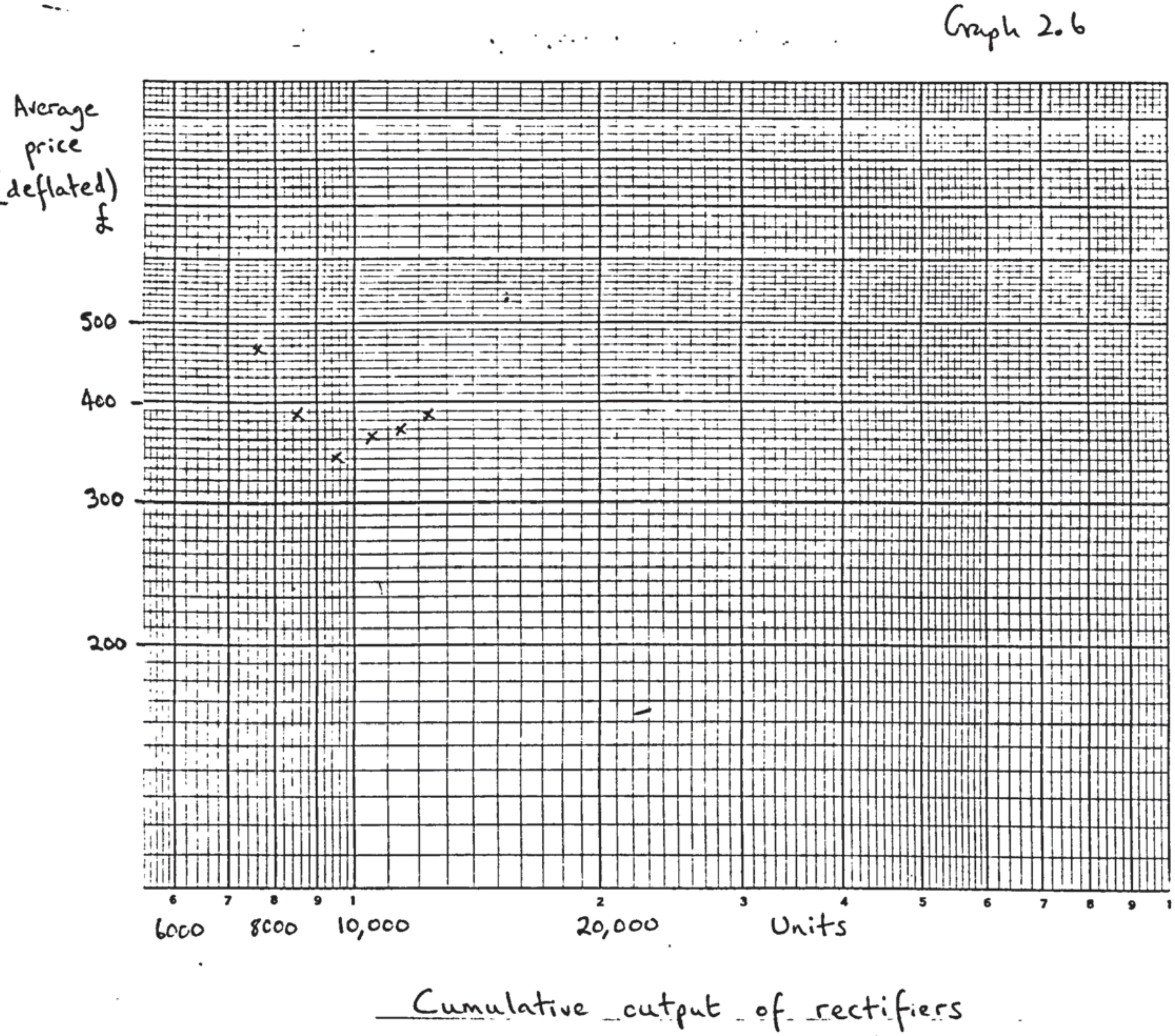
Graph C 2.4 BOC AE (BEAMA data); average price of MIG rectifiers increases 1972- 77



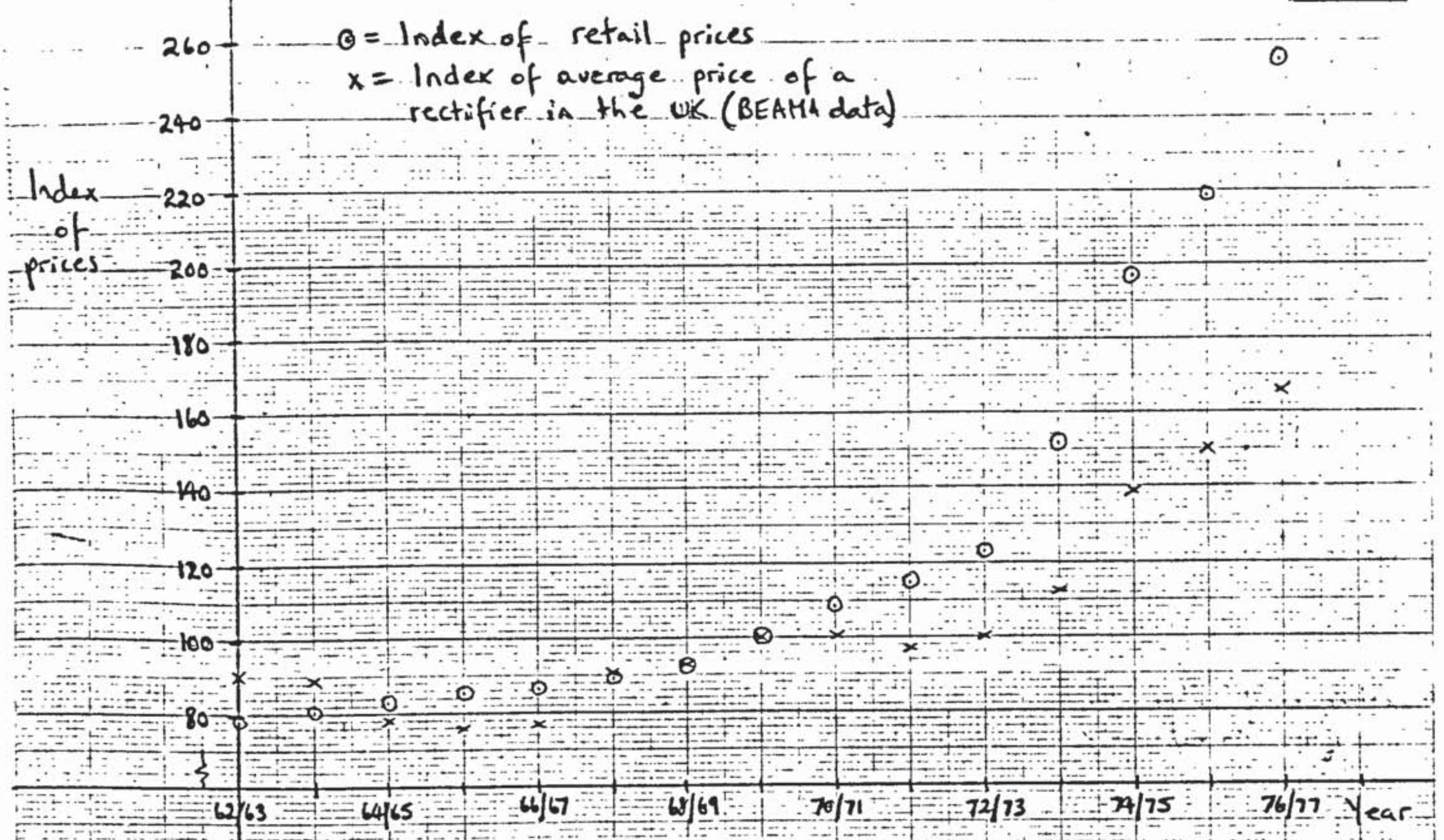
Graph C 2.5 Aggregated company data (BEAMA); average price of TIG rectifiers declines 1972-77



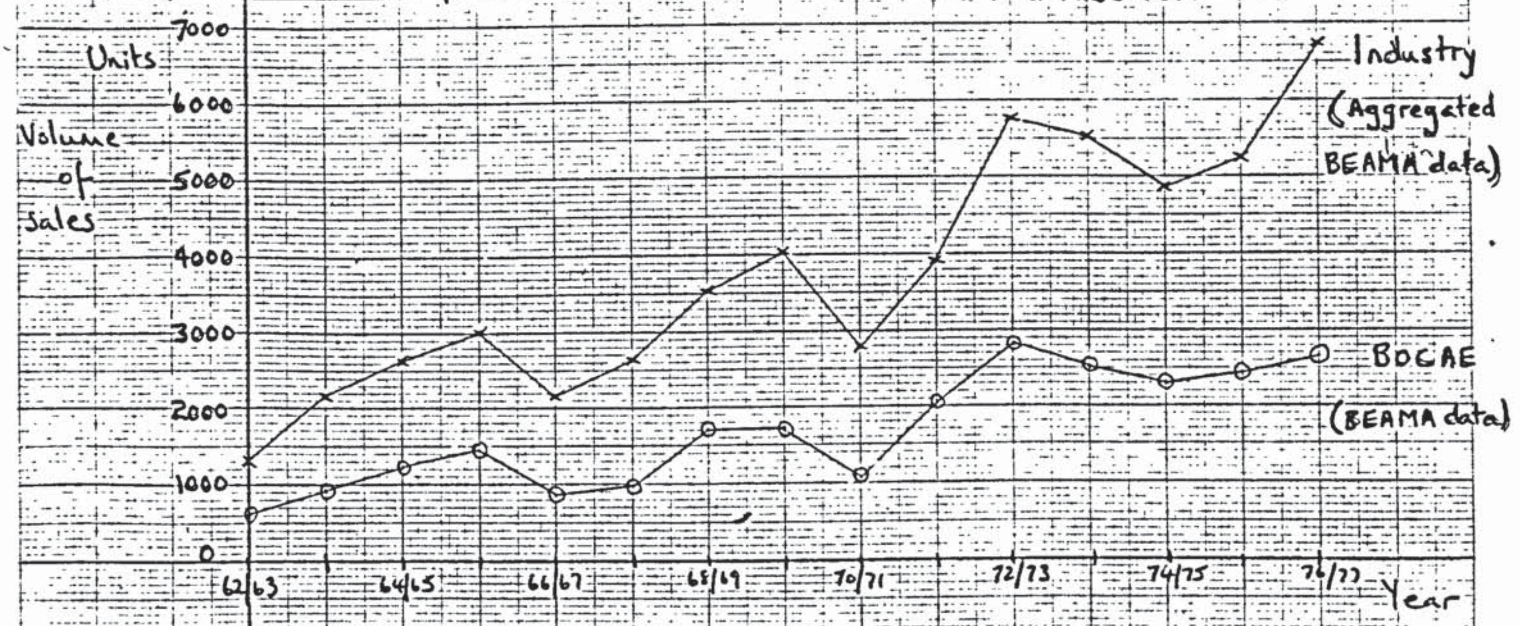
Graph C 2.6 BOC AE (BEAMA data); average price of TIG rectifiers declines 1972-74 then rises 1974-77



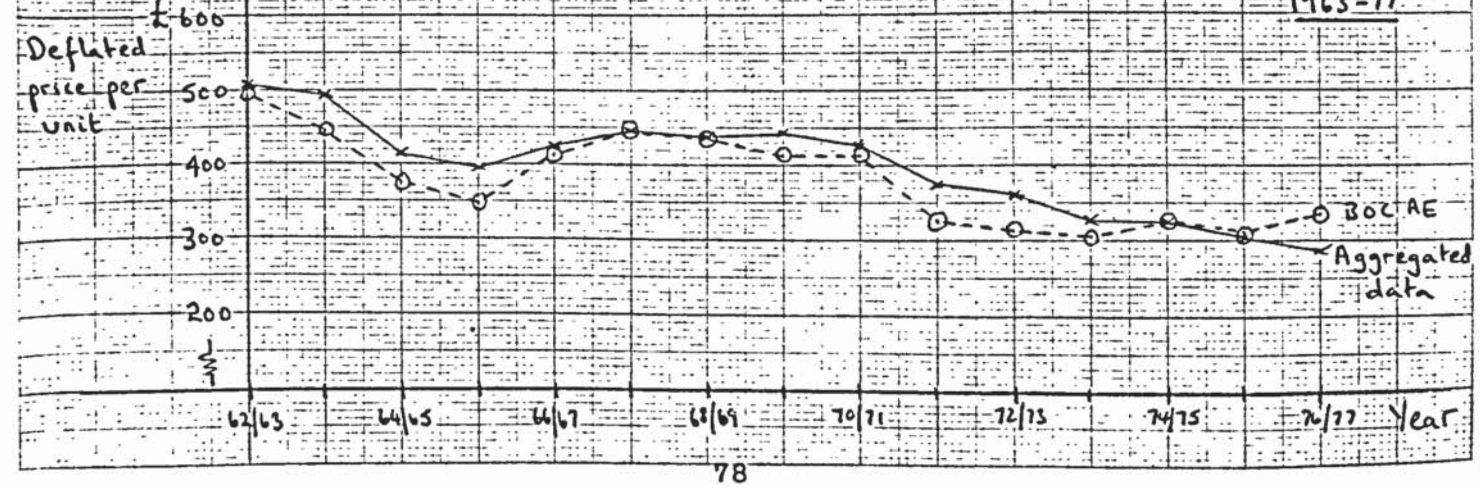
Graph C.2.7 Comparison of average price (aggregated BEAMA data) with deflating index. 1962-77



Graph C.2.8 Output Volumes 1963-77, BOCAE and aggregated data



Graph C.2.9 Comparison of average prices, BOCAE with aggregated data (BEAMA) 1963-77



2.3 <u>Discrepancies in the data submitted to BEAMA</u>

Many personnel at BOC Arc Equipment had doubts about the data both submitted to and received from BEAMA. It was known that submissions from BOC did not cover sales of all rectifiers. Although many had opinions on the reasons for the discrepancy, this had never been properly investigated.

Therefore, before drawing any conclusions from the results of analyses, the validity of the data had to be investigated. The only other consistent source of information on volumes was that of production programs, which reported numbers of each machine produced in the factory. Luckily these documents, dating back to 1969/70, had been kept by the lady clerk in charge of them. Further information was available from the order book for 1967-69, kept by the same lady.

Since other information was available dating back to 1965, it was decided to estimate volumes of production for each machine for the missing years 1965/66, 1966/67 and 1967/68. These were estimated using

i) evidence of serial numbers where available (e.g. from delivery notes)

ii) estimates of scale of production by personnel who were working in the factory at that time, particularly the manager, Charles Alldridge.

Volumes of machines made were summed for each year ending in September (BOC AE financial year), and the total production per year estimated for all rectifiers, MIG, TIG, DC Manual and Plasma.

The results were then compared with BEAMA data for sales of all rectifiers;

	Source		
	BEAMA - Volume of sales	BOC AE-production	Propn BEAMA production
1965/66	1464	2538	57%
1966/67	878	2378	37%
1967/68	992	3148	31%
1968/69	1707	3653	54%
1969/70	1729	3681	47%
1970/71	1095	3335	33%
1971/72	2070	3187	65%
1972/73	2820	3650	77%
1973/74	2540	4842	52%
1974/75	2313	4132	56%
1975/76	2438	3960	62%
1976/77	2660	4461	60%

It was decided to analyse this discrepancy for 1976/77, for which the maximum amount of information was available.

Investigation of data sources 1976/77

The sources of data submitted to BEAMA by BOC Arc Equipment are:

UK sales; Computer tabulation of invoiced UK sales produced by NAC. Special report; Sales by BEAMA classification WP./SA. R.25. Also produced; sister report WP./SA. R.26 which gives the part numbers included in each category.

Export sales; In house computer tabulation produced from invoiced export sales; report number 6, Sales by BEAMA classification.

Both reports are produced quarterly.

In order to check these figures, other sources of data are required. Those available are

i) R.15 - record of UK invoiced sales by product group produced by NAC from same records.

ii) Orders received; the mainline supply office at BOC AE keep a record of quarterly orders received, by part number. These were collected and summed for the year 1976/77.

A comparison of data from differing sources reveals the following:

	Source of Data					
	Production	Orders Received (UK and Export)	BEAMA UK	BEAMA Export	BEAMA Total	R15 UK Sales only
MIG	3068	3215	1259	369	1628	1264
TIG + DC Manual + Plasma	1393	992	825	210	1035	849
TOTAL	4461	4207	2084	579	2663	2113

(Discrepancy between production volume and BEAMA total = 1798)

From this exercise the following is deduced:

a) Production and orders received

These figures can be approximately reconciled as follows:

Production	4461
Less OEM Sales	748
Automatics	117
	3596

Orders Received	4207
Less Forward orders (say)	500
	3707

b) BEAMA figures for UK sales & R.15

Discrepancy of only 29, these should tally exactly as they are basically from the same source, i.e. NAC records of UK invoiced sales.

c) TIG, DC MANUAL + PLASMA

These can be approximately reconciled:

Production figures

TIG, DC MAN + PLASMA	1393
Less OEMs	210
Automatics	117
	1066
Orders Received	992
BEAMA Sales figures	1035

d) MIG

Production figures

MIG	3068
Less OEMs	538
	2530
Orders Received	3215
BEAMA Sales figures	1628

Stock at year end (not recorded in volumes) reported not to include large numbers of MIG rectifiers.

The conclusion is that there is a discrepancy of approximately 900 units between MIG production volumes and MIG sales volumes as recorded for BEAMA, which cannot be explained by increased stocks.

Possible explanation:

i) Part Numbers

Rectifiers manufactured at the Thanet factory are classified under part numbers

e.g.	TM 350	1198012
	TM 225	1198057
	TM SPR	1198058

The sets are despatched to MK where they are assembled into packages containing a torch, cables, etc. Each basic welding set can form the basis of several packages, which are then each given another part number.
e.g. TM 350 is in 7 basic packages and 6 MIGpaks, each with different part bumbers. In addition, sets adapted for export also have a unique part number.

This system causes immediate confusion when recording or trying to reconcile data. The BEAMA classification involves hundreds of part numbers which have to be continually updated.

ii) Specials

Any machine which deviates from specification in any detail is classed as a special and given a different part number. Sales of these sets will not then be picked up when running the BEAMA program.

This particularly applies to machines for export (mainly MIG), which although having only minor changes, are then classed as specials.

iii) Welding sets made for export to foreign manufacturers, e.g. Smitweld, Dube, Arcum. These are given different part numbers in the factory, some but not all of which are picked up on the BEAMA classification.

<u>Summary</u>

The discrepancy of 1798 between production volume and sales volume figures submitted to BEAMA can be partially accounted for as follows:

<u>TIG</u>	OEM Sales	210
	Automatics	117
	Remainder	31
		358

(There will be some discrepancy between production and sales)

<u>MIG</u>	OEM Sales	538
	Other*	902
		1440
	Grand Total	1798

* It is surmised that this figure consists of sales under part numbers not picked up by BEAMA, being either specials, for export, or for foreign manufacturers, or because the list of applicable part numbers has not been updated.

Conclusion

The sales recorded by BEAMA consist of welding sets which conform strictly to product specification, and are sold under the BOC label.
This categorisation excludes 40% (1798/4461) of rectifiers manufactured by the company, and therefore the data does not fairly represent the scale of output or cumulative output.

Consequently, further investigation is required. (part 3)

Appendix C

3. Investigation of the behaviour of average price and cost per unit of rectifiers manufactured by BOC Arc Equipment.

The available data for use in such an investigation consists of

a) Accounts data for BOC Arc Equipment 1965/66 to 1976/77.

b) Accounts data for HWR.

c) Volume of output of production (obtained from HWR).

The main problems involved in dealing with this data are outlined in 3.1, with details of data and adjustments given in 3.2, methodology for testing data in 3.3, results and graphs in 3.4 and conclusion in 3.5.

3.1 Problems encountered in dealing with the data

3.1.1 The period for which data was available, 1965/66 to 1976/77 covers two periods of time during which BOC Arc Equipment and HWR had different relationships.

a) 1965-72, HWR was a separate company, although BOC had a 40% share in it. HWR sold mostly to BOC, but a small proportion of its output of rectifiers was sold to other customers. (See main report, 2.3.2).

b) 1972 onwards, HWR is part of BOC Arc Equipment.

Since the two establishments have always been strongly interlinked (see 2.3.2 main report), the causes and benefits of cost reduction should be equally interlinked. For example, whilst the direct costs at the factory may be benefitting from increased efficiency and improved methods, they are equally affected by the rsults of design and development of new products which is carried out at BOC.

Thus, it was felt that the most consistent behaviour of unit cost would come from treatment of the HWR/BOC Arc Equipment consortium as a whole, for the entire period 1965-77.

The main adjustment required for this was to add data for sales and costs of rectifiers sold to other customers by HWR during the period 1965-72 to sales and costs recorded by BOC Arc Equipment. (See adjustments 3.2.4).

3.1.2 During the period covered by the data several changes were made in the functions of BOC Arc Equipment:

a) MANUAL equipment was sold 1965/66 to 1968/69, then not for three years, and then sold again 1972/73 onwards.

b) Electrodes were sold from 1965/66 to 1968/69 only.

c) From 1973/74, the sales function was taken over by BOC Ltd. Gases Division, and goods for sale in the UK were transferred to BOC Ltd., at a special transfer price. This affected both apparent revenue and marketing costs in the accounts of BOC Arc Equipment.

The changes outlined in (a) and (b) do not affect the investigation, since it is concerned with sales and costs of rectifiers, which are used only in MIG, TIG and PLASMA equipment. (See main report, 2.2.1).

The changes referred to in (c) affect the consistency of sales and costs data for MIG, TIG and PLASMA equipment. Adjustment to deal with this is basically as follows:-

i) Revenue 1973/74 onwards is adjusted from transfer value to market value. (See 3.2.3).

ii) Selling costs 1973/74 onwards have been estimated and added to BOC Arc Equipment costs (See 3.2.3).

3.1.3 In the trading accounts of BOC AE, the value of sales and costs of rectifiers was not recorded as a separate category, but included in data for all MIG equipment, all TIG equipment, etc.

The only guide to the proportion formed by rectifiers alone was provided by some other records of sales data which gave a further split into broad categories within product groups.

e.g. MIG is divided into welding equipment, power sources, Autolynx, packages, etc. Of these, power sources and Autolynx are almost all rectifiers, welding equipment is supposed to be equipment other than rectifiers, but packages are a mixture, i.e. a welding set plus equipment sold as a package.

An attempt to find some estimate of the proportion of MIG and TIG sales formed by rectifiers revealed no significant trend in this proportion, found to be approximately 41% for MIG, and 46% for TIG.
Thus it was assumed that the proportion is constant, and so can be ignored; data for sales and costs of total MIG, TIG and PLASMA equipment is used throughout.

3.1.4 During the period, there were also changes in accounting methods, in particular:

a) Changes in categories of cost. Although not used in this investigation, it was found that all could consistently be placed into five main categories, Manufacture and Distribution, Marketing, Publicity, Research and Development, and Other (including administration).

b) Sales and costs of spare parts and service, originally included in product group categories, were separated out, spares data from 1973/74 onwards, and service data 1974/75 onwards.

In order to make the data consistent, this data has been re-allocated to product groups for these periods. (See 3.2.3).

3.2 Data, adjustments and methodology

See tables 3.1 - 3.8;

Table 3.1	Data on volumes of production
3.2	Raw data from HWR accounts
3.3	Adjustments to HWR accounts
3.4	Raw data from BOC AE accounts
3.5	Adjustments to BOC AE accounts
3.6	Summary of adjusted data BOC AE accounts
3.7	Amalgamation of data HWR & BOC
3.8	Data for joint HWR & BOC companies; deflation of data and sales and costs per unit

Details of data and adjustments

3.2.1 Number of rectifiers produced (See Table 3.1)

The source of data was production programs, 1968/69 onwards, which had been kept by the lady who completed them, plus the order book for all machines made during 1967/68.

The numbers produced for each model were summed for each year ending in September, and these summed for all models to give annual output. Numbers were only included in a specific period if the program was completed in that time.

Volumes of output for 1965/66 and 1966/67 could be estimated from available information, consisting of serial numbers from delivery notes, and estimates of production of each model from personnel who were in close association with the factory at that time. Estimates were adjusted to fall in line with the trend in sales suggested by the BEAMA figures, i.e. with a higher volume of production in 1965/66 than in 1966/67.

3.2.2 Sales and costs of production at HWR (1965/66 to 1976/77)

Source

Annual profit and loss accounts for HWR, 1965/66 to 1976/77, with the omission of 1973/74 for which the documents could not be found.

Data (See Table 3.2)

a) Sales revenue, divided into 'BOC' and 'other'. 'Other' sales consisted of, 1965/66 to 1971/72, sales to Murex and other customers, 1972/73 onwards sales to external home, direct export, BOC Ltd., subsidiaries and direct export to BOC Ltd., subsidiaries.

b) Direct costs, divided into materials purchased, and direct wages and pensions.

c) Fixed costs, divided into administrative, establishment, financial, professional, other, and carriage.

d) Stock, adjustments, depreciation.

e) Central costs 1974/75 to 1976/77 (ignored).

Adjustments

a) Stock levels were used to adjust materials purchased to find estimates of materials consumed. It was thought to be more representative of actual materials consumed if stock level and purchases figures were deflated first, thus giving everything in constant value (See Table 3.3).

3.2.3 Sales and costs incurred by the trading by BOC Arc Equipment

Source

Monthly and annual trading accounts of BOC Arc Equipment, 1965/66 to 1976/77.

Data (See Table 3.4)

a) Sales revenue, contribution and fixed costs for:

MIG & TIG	1965/66 to 1976/77
PLASMA	1973/74 to 1976/77 (no PLASMA pervious to this)
MANUAL	1965/66 to 1968/69, 1972/73 to 1976/77
AUTOMATICS	1965/66 to 1968/69
ELECTRODES	1965/66 to 1968/69
HIRST DIRECT	1972/73 to 1976/77
PARTS	1973/74 to 1976/77
SERVICE	1974/75 to 1976/77

b) Fixed costs are also divided into categories, but these are not used in this analysis.

c) Regional costs, district costs, central costs, etc.

Adjustments (See Table 3.5)

a) Data for MANUAL and ELECTRODES excluded since it is not relevant for this analysis.

b) Any type of regional or central cost has been excluded since
   i) These refer to the share of central costs imposed by BOC Ltd., and thus are not within the control of BOC Arc Equipment.
   ii) Categories are not consistent.

c) Parts and service data for sales and costs for 1973/74 and 1974/75 onwards has been allocated back into MIG, TIG and PLASMA product groups in order to make data 1965/66 to 1976/77 consistent.

i) Actual sales of spares and service was known for MIG, TIG/PLASMA, MANUAL (See Table 3.5).

ii) Direct and fixed costs for spares and service were then allocated to these product groups on the basis of sales figures (See Table 3.5).

d) Sales and costs for automatics 1965/66 to 1968/69 were added to those for other equipment manufacturers, since this was their main market outlet.

e) The adjustment to compensate for sales revenue 1974/75 onwards being at transfer value for UK sales was as follows (See 3.1.2 (c))

i) Sales for MIG, TIG & PLASMA divided into Home Sales and Export.

ii) Home sales multiplied by $\frac{5}{4}$ to adjust value of sales to list price valuation, since transfer price is 80% of list price.

iii) The result of (ii) multiplied by $\frac{93}{100}$ since most sales are made not at list price, but at discount price, the average of which is 7%.

iv) Hence, new valuation of sales revenue for MIG, TIG and PLASMA 1974/75 onwards estimated by

$$(\text{Home sales} \times \frac{5}{4} \times \frac{93}{100}) + \text{Export Sales}$$

(Export sales unaffected) (See Table 3.5).

f) Adjustment to fixed costs to compensate for the selling costs transferred to Gases Division from 1974/75 onwards.

The assumption was made that these costs would have been maintained at the same level, when deflated. Thus, the deflated cost for marketing in 1973/74, £137k, was inflated and added to fixed costs for 1974/75 onwards (See Table 3.5).

Table 4.6 gives the summary of adjusted data for BOC Arc Equipment trading in MIG, TIG and PLASMA. Note that figures for sales and direct cost for Hirst direct 1974/75 are taken from HWR data as this was felt to be a more accurate figure.

3.2.4 <u>Amalgamation of HWR & BOC Arc Equipment data for manufacture of and trading in rectifiers</u>

a) <u>Sales</u>; Total sales consist of

i) Sales recorded by BOC AE 1965/66 to 1976/77

plus ii) Sales by HWR to 'other' customers 1965/66 to 1971/72.

b) <u>Direct costs</u>; direct costs incurred by the joint business consist of the direct costs incurred by BOC Arc Equipment, adjusted in the following ways;

i) 1965/66 to 1971/72. Since direct costs recorded by BOC during this period include cost of purchase of rectifiers from HWR at a transfer price which covers fixed costs and profit margin, true direct costs for this period consist of:

Direct cost recorded by BOC AE

<u>Less</u> Transfer value of goods bought from HWR

<u>Plus</u> Direct cost of all goods manufactured by HWR (at adjusted value, see 3.2.2).

ii) 1972/73 to 1976/77. Direct costs recorded by BOC Arc Equipment are adjusted by the element of cost incurred by HWR, which has been altered to represent material consumed in constant money terms (See 3.2.2). Adjusted data hence consists of:

Direct costs recorded by BOC Arc Equipment

<u>Less</u> Unadjusted direct costs incurred by HWR

<u>Plus</u> Adjusted direct costs incurred by HWR (See Table 3.7).

c) <u>Fixed Costs</u>; Total fixed costs consist of

i) Fixed costs recorded by BOC Arc Equipment

ii) Fixed costs incurred by HWR 1965/66 to 1971/72.

3.2.5 Data for joint venture, HWR & BOC

See Table 3.8.

The data for sales revenue, direct and fixed costs for the joint venture is then:

a) Deflated using the Index of Wholesale prices of Home Sales of all Manufactured Products (given in Table 3.8, line 5).

b) Divided by volume of output of production for each year, to give average sales and cost per unit of production for each year.

3.2.6 Data for MIG & TIG, separately

See Table 3.9.

Sales and direct cost data for MIG and TIG separately is taken from adjusted data for BOC Arc Equipment. (See Table 3.6). These figures are then deflated and divided by volume of output for MIG and TIG respectively, to obtain deflated sales and direct cost per unit for each, 1965/66 to 1976/77. It should be pointed out that this data is fraught with inaccuracies since:

a) Sales and cost data does not include sales from Hirst Direct and to other equipment manufacturers, since data is not available on the split of these sales between MIG and TIG. Volume of output however does include machines sold via these outlets.

b) As far as possible, data for TIG/PLASMA excludes that referring to automatics. However, value of sales 1969/70 onwards may contain some automatics sales.

3.2.7 Estimation of cumulative output for beginning of period for which data is available.

i) Total rectifier production

In this case, since it is known that BOC Arc Equipment had been producing rectifiers since the early 1950s, cumulative output at the end of 1965/66 has been estimated by totalling estimated volumes of output for the previous fourteen years. The method is a variation on that given in 2.1.2 (c) of this appendix.

Firstly, the average compound growth rate in annual volumes of output is calculated for the period for which data is available, i.e. 1965/66 to 1976/77. Linear regression techniques applied to this data estimate the best straight line through the data to be given by

$y = -8415.58 + 167.776x$ (C = 0.83, F = 23.1)

From which, the average compound growth rate per annum is estimated by $r = \sqrt[11]{\frac{4503.19}{2657.60}} - 1 = 0.0491$

Then, cumulative output by the end of 1965/66 is estimated by

$$S = Co\left[\frac{1 - \left(\frac{1}{1+r}\right)^{14}}{1 - \frac{1}{1+r}}\right] \quad \text{(Sum of G.P. with ratio } \frac{1}{1+r} < 1\text{)}$$

Where Co is the output volume in 1965/66.

$$\text{i.e. } S = 2538 \frac{(1 - 0.5111)}{(1 - 0.9532)} = 26508$$

Cumulative output 1965/66 onwards given in Table 3.8.

ii) <u>MIG & TIG rectifier production, separately</u>

Cumulative output for each at the end of 1965/66 was estimated by using proportions of the total cumulative output for 1965/66, estimated in (i) overleaf. The proportions used were the average proportions of annual volume of output formed by MIG and TIG rectifiers, respectively.

MIG: Cumulative output estimated by

$0.6208 \times 26508 = 16456$

TIG: Cumulative output estimated by

$0.3792 \times 26508 = 10052$

See Table 3.9 for cumulative output 1965/66 onwards.

Table 3.1

Numbers of Rectifiers Produced at the Factory

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
	Number of Units											
MIG												
Up to 150A	-	-	-	352	690	796	890	791	819	721	847	700
151 to 200A	1210	1211	1012	776	845	703	502	752	861	501	566	631
201 to 350A	60	70	140	171	169	536	443	752	953	763	650	1308
Over 350A	25	372	448	766	804	354	349	258	458	481	391	429
TOTAL MIG	1295	1653	1600	2065	2508	2389	2184	2553	3091	2466	2454	3068
TIG & PLASMA												
Up to 150A	114	164	180	84	95	44	139	87	261	140	56	160
151 to 200A	30	32	60	89	61	115	108	84	53	-	-	-
201 to 350A	136	136	361	435	368	425	363	424	809	686	476	422
Over 350A	511	545	668	701	383	215	195	300	332	578	741	694
TOTAL TIG & PLASMA	791	877	1269	1309	907	799	805	895	1455	1404	1273	1276
SUBMERGED ARC (AUTOMATICS)	150	150	279	279	266	147	198	202	296	262	233	117
TOTAL (ALL RECTIFIERS)	2236	2680	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461
ADJUSTED TOTAL	2538	2378	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461

See 3.2.1 for details of source of data, etc.

Table 3.2

Raw Data on Sales and Costs at HWR (the factory)

Sales and costs per annum (£'000)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES												
BOC	446	352	563	897	968	816	771	704		1677	2063	3135
Other	93	104	111	182	261	235	157	281		367	339	457
TOTAL	539	456	674	1079	1229	1051	928	985		2044	2402	3592
DIRECT COSTS												
*Material Consumed	321	242	353	550	655	558	512	753		1361	1430	2199
Direct Wages & Pensions	45	50	83	135	137	121	120	140		255	323	484
TOTAL	366	292	436	685	792	679	632	893		1616	1753	2683
** FIXED COSTS	45	51	64	87	118	126	126	162		296	356	567
TOTAL FIXED & DIRECT COSTS	411	343	500	772	910	805	758	1055		1912	2109	3250
ADJUSTMENTS		(2)	(2)	(1)	(4)	(5)	(7)	(7)		(14)	(11)	(9)
DEPRECIATION	5	5	7	9	12	14	15	18		22	21	25
CENTRAL COSTS										60	80	101
TOTAL COSTS	416	346	505	780	918	814	766	1066		1980	2199	3367
PROFIT	123	110	169	299	311	237	162	(81)		64	203	225

(See 3.1.2 for details of source and data)

* Material purchased adjusted by difference in stock levels at beginning and end of year.

** Breakdown of fixed costs given later. (see

Table 3.3

Adjustments to Costs at HWR (the factory)

Adjustment to direct costs per annum (£'000)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Deflating Index	85.6	86.5	89.9	93.4	100	109	114.8	123.2	152.0	188.7	218.6	258.3
Original Data (Table 3.2)												
Materials Purchased	355	245	388	628	656	492	539	936		1559	1861	2233
Stock at beginning	41	75	78	113	191	192	126	153		757	955	1385
Stock at year end	75	78	113	191	192	126	153	336		955	1385	1446
Materials Consumed	321	242	353	550	655	558	512	753		1361	1431	2172
Deflated Before Stock Adjustment												
Materials Purchased	415	283	432	672	656	451	469	760		826	851	864
Stock at beginning	49	87	90	126	204	192	115	133		401	506	634
Stock at year end	87	90	126	204	192	115	133	272		506	634	560
Materials Consumed	377	280	396	594	668	528	451	621		721	723	938
Material Consumed (Inflated)	323	242	356	555	668	576	518	765		1361	1580	2423
Direct Wages and Pensions (Unaltered) (Table 3.2)	45	50	83	135	137	121	120	140		255	323	484
	368	292	439	690	805	697	638	905		1616	1903	2907

Table 3.4

Raw Data for BOC Arc Equipmemt from Trading Accounts

Sales, contribution and fixed costs per annum (£'000)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES												
MIG	806	738	808	1142	1480	1409	1412	1983	1687	1479	1677	2220
TIG	568	504	597	680	694	757	939	1168	1005	1103	1208	1653
PLASMA									196	175	195	207
MANUAL	953	799	795	947	-	-	-	835	1127	1139	1326	1404
AUTOMATICS	329	281	321	358	-	-	-	-	-	-	-	-
ELECTRODES	56	119	18	130	-	-	-	-	-	-	-	-
HIRST DIRECT(OEM)	-	-	-	-	-	-	-	281	246	634	480	736
PARTS									1060	1176	1183	1494
SERVICE										98	155	205
TOTAL	2712	2441	2539	3257	2174	2166	2351	4267	5321	5804	6224	7919
CONTRIBUTION												
MIG	360	361	393	564	642	590	647	1013	680	524	633	834
TIG	210	209	215	263	297	334	412	587	465	487	571	721
PLASMA									79	60	82	94
MANUAL	252	197	211	274				180	233	256	224	316
AUTOMATICS	125	130	142	169								
ELECTRODES	37	34	3	45								
HIRST DIRECT(OEM)								87	54	157	112	134
PARTS									591	704	791	795
SERVICE										22	56	55
	984	931	964	1315	939	924	1059	1867	2102	2210	2469	2949

Table 3.4 Continued

Raw Data for BOC Arc Equipment from Trading Accounts

Direct and fixed costs per annum (£'000)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
DIRECT COSTS (SALES - CONTRIBUTION)												
MIG	446	377	415	578	838	819	765	970	1007	955	1044	1386
TIG	357	295	382	417	397	423	527	581	540	616	637	932
PLASMA									117	115	113	113
MANUAL	701	602	584	673				655	894	883	1102	1088
AUTOMATICS	204	151	179	189								
ELECTRODES	20	85	15	85								
HIRST DIRECT/OEM								194	192	477	368	602
PARTS									469	472	392	699
SERVICE										76	99	150
TOTAL	1728	1510	1575	1942	1235	1242	1292	2400	3219	3594	3755	4970
FIXED COSTS*												
MIG	215	254	337	392	506	584	556	753	709	579	562	618
TIG	102	127	171	188	193	206	236	381	320	313	383	475
PLASMA									53	91	64	67
MANUAL	73	125	165	209				171	173	190	215	341
AUTOMATICS	186	183	216	197								
ELECTRODES	9	15	16	34								
HIRST DIRECT/OEM								41	32	99	137	198
PARTS									278	264	373	390
SERVICE										30	45	44
TOTAL	585	704	905	1020	699	790	792	1346	1565	1566	1779	2133
Not Included	Regional costs, District costs, Central costs, Germany, H.O. Allocated costs.											
Profit	399	227	59	259	240	137	267	521	537	647	690	816

*Breakdown of Fixed costs given later (See Appendix H)

N.B. FIXED COSTS ALLOCATED AMONGST MIG, TIG, ETC.

Table 3.5

Adjustments to data for BOC Arc Equipment Sales and Costs

Sales per annum (£'000)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MIG												
Sales (Table 3.4)	806	738	808	1142	1480	1409	1412	1983	1687	1479	1677	2220
+ Spares									657	672	666	839
+ Service										71	110	120
SUB-TOTAL	"	"	"	"	"	"	"	"	2344	2222	2453	3179
Percentage Home Sales in original data										.649	.584	.652
Home Sales - proportion of above										1443	1432	2074
Home Sales x $\frac{5}{4}$ x $\frac{93}{100}$										1677	1665	2411
TOTAL MIG ADJUSTED SALES	806	738	808	1142	1480	1409	1412	1983	2344	2456	2686	3516
TIG + PLASMA												
Sales (Table 3.4)	568	504	597	680	694	757	939	1168	1201	1278	1403	1860
+ Spares									363	464	475	594
+ Service										27	45	85
SUB-TOTAL	"	"	"	"	"	"	"	"	1564	1769	1923	2539
Percentage Home Sales in original data										.724	.701	.711
Home Sales - proportion of above										1281	1348	1806
Home Sales x $\frac{5}{4}$ x $\frac{93}{100}$										1489	1567	2099
TOTAL TIG ADJUSTED SALES	568	504	597	680	694	757	939	1168	1564	1977	2142	2832

N.B. See 3.2.3 for details of adjustments

Table 3.5 Continued

Adjustments to data for BOC Arc Equipment Sales and Costs

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Direct costs per annum (£'000)												
MIG												
Original data	446	377	415	578	838	819	765	970	1007	955	1044	1386
plus share of Parts & Service									290	320	285	479
TOTAL	446	377	415	578	838	819	765	970	1297	1275	1329	1865
TIG & PLASMA												
Original data	357	295	382	417	397	423	527	581	657	731	750	1045
plus share of Parts & Service									161	211	191	339
	357	295	382	417	397	423	527	581	818	942	941	1384
Fixed costs per annum (£'000)												
MIG												
Original data	215	254	337	392	506	584	556	753	709	579	562	618
Share of parts & service									172	171	242	245
	215	154	337	392	506	584	556	753	881	750	804	863
TIG & PLASMA												
Original data	102	127	171	188	193	206	236	381	373	404	447	542
Share of parts& service									95	110	162	173
	102	127	171	188	193	206	236	381	468	514	609	715
AUTOMATIC/HIRST DIRECT	186	183	216	197				41	32	53	137	198
TOTAL FIXED COSTS	503	564	724	777	699	790	792	1175	1381	1317	1550	1776

Table 3.5 Continued

Adjustments to data for BOC Arc Equipment Sales and Costs

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
+ COMPENSATED SELLING COSTS												
DEFLATED										137	137	137
INFLATED										258	299	354
TOTAL FIXED COSTS	503	564	724	777	699	790	792	1175	1381	1575	1849	2130

Table 3.6

Adjusted data for BOC Arc Equipment

Sales Revenue & Costs £'000 per annum

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES												
MIG (Table 3.5)	806	738	808	1142	1480	1409	1412	1983	2344	2456	2686	3516
TIG/PLASMA (Table 3.5)	568	504	597	680	694	757	939	1168	1564	1977	2142	2832
AUTOMATICS/HIRST DIRECT/ OEM (Table 3.4)	329	281	321	358				281	246	370	480	736
TOTAL	1703	1523	1726	2180	2174	2166	2351	3432	4154	4803	5308	7084
DIRECT COSTS												
MIG	446	377	415	578	838	819	765	970	1297	1275	1329	1865
TIG/PLASMA	357	295	382	417	397	423	527	581	818	942	941	1384
AUTOMATICS/HIRST DIRECT/ OEM	204	151	179	189				194	192	286	368	602
TOTAL	1007	823	976	1184	1235	1242	1292	1745	2307	2503	2638	3851
FIXED COSTS												
MIG	215	254	337	392	506	584	556	753	881	750	804	863
TIG/PLASMA	102	127	171	188	193	206	236	381	468	514	609	715
AUTOMATICS/HIRST DIRECT/ OEM	186	183	216	197				41	32	99	137	198
+ SELLING COSTS (ESTIMATED)										258	299	354
TOTAL	503	564	724	777	699	790	792	1175	1381	1621	1849	2130

N.B. Figures for sales and direct costs for Hirst Direct sales 1974/75 taken from HWR accounts as these were felt to be more accurate.

Table 3.7

Adjustments to amalgamate data for HWR and BOC AE

Sales Revenue and Costs per annum £'000

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES												
BOC AE (Table 3.6)	1703	1523	1726	2180	2174	2166	2351	3432	4154	4803	5308	7084
Plus HWR 'OTHER' (Table 3.2)	93	104	111	182	261	235	157					
TOTAL SALES	1796	1627	1837	2362	2435	2401	2508	3432	4154	4803	5308	7084
DIRECT COSTS												
BOC AE (Table 3.6)	1007	823	976	1184	1235	1242	1292	1745	2307	2503	2638	3851
Less HWR Transfer Value (Table 3.2)	446	352	563	897	968	816	771					
Less HWR Direct Cost (Table 3.2)								893		1616	1753	2683
Plus HWR Adjusted Direct Cost (Table 3.3)	368	292	439	690	805	697	638	905		1616	1903	2907
TOTAL	929	763	852	977	1072	1123	1159	1757	2307	2503	2788	4075
FIXED COSTS												
BOC AE (Table 3.6)	503	564	724	777	699	790	792	1175	1381	1621	1849	2130
Plus HWR (Table 3.2)	45	51	64	87	118	126	126					
	548	615	788	864	817	916	918	1175	1381	1621	1849	2130

Table 3.8 <u>Data for joint companies, BOC Arc Equipment and HWR deflated, with calculations of average sales and costs per unit for each year.</u>

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
	Sales Revenue and costs per annum £'000											
DATA (See Table 3.7)												
SALES	1796	1627	1837	2362	2435	2401	2508	3432	4154	4803	5308	7084
DIRECT COSTS	929	763	852	977	1072	1123	1159	1757	2307	2503	2788	4075
FIXED COSTS	548	615	788	864	817	916	918	1175	1381	1621	1849	2130
DIRECT PLUS FIXED COSTS	1477	1378	1640	1841	1889	2039	2077	2932	3688	4124	4637	6205
DEFLATING INDEX	85.6	86.5	89.9	93.4	100	109	114.8	123.2	152.0	188.7	218.6	258.3
	Sales Revenue and costs per annum, deflated £'000											
SALES	2098	1881	2043	2529	2435	2203	2185	2786	2733	2545	2428	2742
DIRECT COST	1085	882	948	1046	1072	1030	1009	1426	1518	1326	1275	1578
FIXED COST	640	711	876	925	817	840	800	954	908	859	846	824
DIRECT PLUS FIXED COST	1725	1593	1824	1971	1889	1870	1809	2380	2426	2185	2121	2402
	Units per annum											
Annual Output of production (Table 3.1)	2538	2378	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461

Table 3.8 Continued — Data for joint companies, BOC Arc Equipment and HWR deflated, with calculations of average sales and costs per unit for each year.

	Average sales and cost per unit £											
	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Average Sales per unit	827	791	649	692	661	661	686	763	564	616	613	615
Direct Cost per unit	427	371	301	286	291	309	317	391	313	321	322	353
Fixed Cost per unit	252	299	278	253	222	252	251	261	188	208	213	185
Fixed and Direct Cost per unit	679	670	579	539	513	561	568	652	501	529	535	538
Cumulative Output (See 3.2.7)	26508	28886	32034	35687	39368	42703	45890	49540	54382	58514	62974	66395

Table 3.9

Data for MIG & TIG taken separately

MIG; Sales and Direct Cost per Unit (£)

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES (Table 3.6) (£'000)	806	738	808	1142	1480	1409	1412	1983	2344	2456	2686	3516
Deflated Sales* (£'000)	942	853	899	1223	1480	1293	1230	1610	1542	1302	1229	1361
Volume of output (Table 3.1, Units)	1295	1653	1600	2065	2508	2389	2184	2553	3091	2466	2454	3068
Deflated Sales per Unit (£)	727	516	562	592	590	541	563	631	499	528	501	444
DIRECT COSTS (Table 3.6, £'000)	446	377	415	578	838	819	765	970	1297	1275	1329	1865
Deflated* (£'000)	521	436	462	619	838	751	666	787	853	676	608	722
Deflated D. Cost per Unit (£)	402	264	289	300	334	314	305	308	276	274	248	235

* Using Index of prices from Table 3.8

Table 3.9 Continued

Data for MIG & TIG taken separately

	TIG & PLASMA: Sales and Direct Cost per Unit (£)											
	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SALES (Table 3.6) (£'000)	568	504	597	680	694	757	939	1168	1564	1977	2142	2832
Deflated Sales* (£'000)	664	583	664	728	694	694	818	948	1029	1048	980	1096
Volume of output (Table 3.1, Units)	791	877	1269	1309	907	799	805	895	1455	1404	1273	1276
Deflated Sales per Unit (£)	837	664	523	556	765	869	1016	1059	707	746	770	859
DIRECT COSTS (Table 3.6 £'000)	357	295	382	417	397	423	527	581	818	942	941	1384
Deflated* (£'000)	417	341	425	446	397	388	459	472	538	499	430	536
Deflated D. Cost per Unit (£)	527	389	335	341	438	486	570	527	370	355	338	420

* Using Index of prices from Table 3.8

Table 3.9 Continued

Data for MIG & TIG taken separately

	Cumulative Output (Units)											
	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MIG	16456	18109	19709	21774	24282	26671	28855	31408	34499	36965	39419	42487
TIG	10052	10929	12198	13507	14414	15213	16018	16913	18368	19772	21045	22321

Table 3.10 Calculation of 'profit margin' per unit

	Sales value, total cost and profit margin per unit, per annum, £											
	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Average Sales per unit (Table 3.8)	827	791	649	692	661	661	686	763	564	616	613	615
Total Cost per unit (Table 3.8)	679	670	579	539	513	561	568	652	501	529	535	538
'Profit margin' per unit	148	121	70	153	148	100	118	111	63	87	78	77

3.3 Methodology

At this stage the only model tested was the experience curve model (see below for details), with results as given in 3.4.

For results of testing of alternative models on this data, see Chapter 6.

3.3.1 Methodology used in testing experience curve model

a) Model; $\log c = a - b \log V$

where c = average selling price, as represented by value of sales per unit, or cost per unit.

V = cumulative output

a, b are parameters of the model.

A test of the relationship between log c and log V is obtained by testing the hypothesis b = o, using technique of linear regression to obtain a sample estimate of b (Appendix B.1.)

b) Data used in testing of model

i) All rectifiers;

Sales value per unit, 1965/66 - 1976/77

Direct cost per unit, " "

Fixed cost per unit, " "

Total cost per unit, " "

ii) MIG & TIG rectifiers, taken separately

(See Table 3.8)

Sales value per unit, 1965/66 - 1976/77

Direct cost per unit, " "

(See Table 3.9)

The results of statistical tests are given in 3.4.

3.3.2 Methodology used in additional analyses

a) Difference between sales value and total cost per unit

i) Significance of the difference between the 'slopes' of the best fitting experience curve models for each set of data, i.e. that of 83.0% for sales value per unit, and 86.5% for total cost per unit.

This is indicated by the difference in slopes of the linear models through the transformed data (i.e. once logs have been taken).

If the underlying models for these two sets of data have slopes

b_1 for sales value per unit

and b_2 for total cost per unit

hypothesis $b_1 = b_2$ may be tested using the sample estimates, $\underline{b1}$, $\underline{b_2}$ say, obtained from the two sets of data.

The method consists of using linear regression to estimate the best fitting straight lines through each of the sets of data, and through the two sets combined and treated as one set.

The excess of the sum of both regression sums of squares obtained from the separate models over that obtained from the combined model indicates whether the data does come from two models with differing slopes. The significance of the difference is shown using analysis of variance techniques, by comparing the ratio of the mean squares of the excess and the residual sum of squares.

For results see 3.4.

ii) Analysis of trend in annual difference between sales value and total cost per unit.
The difference between the deflated sales value per unit and deflated total cost per unit was calculated for each year 1965/66 to 1976/77 (See Table 3.10).
The resulting data for profit margin per unit was tested for a linear trend over this time interval.

i.e. Linear regression techniques were used on this set of data using the model

$y = a + bT$

where y = deflated 'profit margin per unit'

T = time in years

i.e. 1965/66 $T = 1$... 1976/77 $T = 12$

in order to test the hypothesis $b = 0$, and to find the best estimate for b from the data.

b) Analysis of trend in direct cost per unit.

The deflated values of direct cost per unit (see Table 3.9) were tested using the same model as in (ii) overleaf.

For results see 3.4.

3.4 Results of analyses of data from BOC Arc Equipment and HWR, treated as a joint business.

The results of the testing of the experience curve model on the various sets of data are given in Table 3.11.

However, in plotting graphs for the data, it became evident that there could be trends in the behaviour of sales and costs per unit of rectifiers, over and above those indicated by the experience curve models (See graphs 3.6 and 3.8).

Initial queries were concerned with the significance of these trends and specifically with;

i) The apparently narrowing gap between sales value and total cost per unit for a rectifier.

ii) The behaviour of direct cost per unit.

It was felt that additional analysis to determine the significance of these trends was essential, and these were carried out immediately. Analyses consisted of the following:

i) The significance of the difference between the slopes of the experience curve models for sales value and total cost per unit

ii) Any trend in individual values of the 'profit margin per unit', i.e. sales value less total cost per unit, over the time 1965/66 to 1976/77.

iii) Any trend in direct cost per unit over the same time interval.

For details of methodology used, see 3.3.2 of this Appendix.

The results of these analyses are given in detail in 3.4.1, followed by a summary of all results in 3.4.2.

3.4.1 Results of additional analyses

a) Testing of significance of difference in slopes between the experience curve models for sales value per unit and total cost per unit.

For method, see 3.3.2.

i) Fitting of individual models

Model; $\log c = a - b \log V$

where c = sales value or total cost per unit (deflated)

V = cumulative output

a, b are parameters of the model

Data for sales value per unit

estimated value of b, $\underline{b_1} = 0.268$

Regression sum of squares	0.01504
Residual sum of squares	0.01185
Total sum of squares	0.02689

Data for total cost per unit

estimated value of b, $\underline{b_2}$ = 0.208

Regression sum of squares	0.00982
Residual sum of squares	0.01263
Total sum of squares	0.02245

ii) Fitting of linear model to combined sets of data

Estimated value of b, $\underline{b_3}$ = 0.226

Regression sum of squares 0.02458

iii) Testing of individual models against combined model

Sum of regression sums of squares of individual models = 0.01504 + 0.00982 = 0.02486

ANOVA

	Sum of squares	Df	MS	MS Ratio
Regression on combined data	0.02458	1		
Excess of sum of individuals over combined model	0.00028	1	0.00028	0.22876
Residual	0.02448	20	0.001224	
Total (Sum of totals for both)	0.04934	22		

Comparison of the mean square ratio for the excess with the residual sum of squares with the F ratio with 1,20 degrees of freedom shows that the sum of regression sums of squares from the two individual models is not significantly greater than that obtained from the combined model.

Hence, the evidence supports the hypothesis that $b_1 = b_2$ i.e. the difference in slopes between the two models is not statistically significant.

b) Trend in 'profit margin' per unit

Linear regression analysis of the relationship between the 'profit margin' per unit, i.e. the difference between sales value and total cost per unit, and the numb er of years that have elapsed, gives the best fitting line through the data as

$y = 143.61 - 5.61x$

where y = sales value less total cost per unit (deflated)

x = 1 1965/66... x = 12, 1976/77

c = 0.63 ($R^2 = 0.40$), F ratio 6.57 significant at 5.0% level.

Average compound rate of decline 1965/66 to 1976/77 is estimated to be 5.5% p.a.

c) Direct cost per unit

Linear regression analysis of the relationship between direct cost per unit and elapsed time gives the best fitting straight line through the data to be

$y = 348.77 - 2.35x$

where y = direct cost per unit (deflated)

x = 1 1965/66... x = 12, 1976/77

c = 0.41 ($R^2 = 0.16$) F ratio 0.17 is not significant at the 5% level.

Average compound rate of decline from 1965/66 to 1976/77 estimated to be 0.71% p.a.

Table 3.11 BOC AE data; Results of fitting of experience curve model

Data	Equation of line	C-rat	F rat (sig. level)	Experience curve slope
1976/77 (12 readings)				
Average price	y = 4.074 - 0.268x	-.72 (R^2 = .52)	10.7 (1.0%)	83.02%
Total cost per unit (Direct & fixed costs)	y = 3.721 - 0.208x	-.61 (R^2 = .37)	6.03 (5.0%)	86.54%
Direct cost per unit	y = 2.855 - 0.072x	-.18 (R^2 = .03)	.34 (not sig.)	95.1%
Fixed cost per unit	y = 4.206 - 0.395x	-.78 (R^2 = .61)	15.9 (1.0%)	76.0%
Data for MIG & TIG (price only)				
1966-77				
MIG				
Average price per unit	y = 3.892 - 0.259x	-.63 (R^2 = .40)	6.715 (5.0%)	83.6%
Direct cost per unit	y = 3.751 - 0.290x	-.64 (R^2 = .41)	7.03 (2.5%)	82.1%
TIG				
Average price per unit	not significant	.34 (R^2 = .11)	1.36 (not sig.)	
Direct cost per unit	not significant	-.17 (R2 = .02)	0.29 (not sig.)	

3.4.2 Summary of Results

a) The fit of the experience curve model

i) Statistical test supported the hypothesis of an experience curve relationship between each of sales revenue per unit, total cost per unit, and fixed cost per unit and cumulative output. In each case the fit of the model was significant at a level of at least 5%, with values of $R^2 \geqslant 37\%$ (Graphs 3.1, 3.2 & 3.3).

ii) Analysis of available data did not support the hypothesis of a relationship betwwen direct cost per unit and cumulative output, using the experience curve model (Graph 3.3). Additional analysis showed that there was no significant linear trend in direct cost per unit over the period in question, (3.4.1 (c)).

iii) When data for MIG and TIG rectifiers was analysed separately, sales value and direct cost per unit for MIG were each fitted by an experience curve model, at significance levels of 5% and 2.5% respectively (Graph 3.5).

Results from TIG data did not support the hypothesis of an experience curve relationship between either sales value or direct cost per unit and cumulative output (Graph 3.6).

b) Trends in sales value per unit and cost per unit

i) Sales value per unit, for all rectifiers, has declined over the period (experience curve 'slope' 83%). However, there are periods of time when it is increasing, particularly 1967/68 to 1972/73, and 1973/74 (Graph 3.7).

ii) Total cost per unit has declined over the whole period (experience curve 'slope' 86.5%), but there are also periods when it is increasing, in particular from 1968/69 to 1972/73, and 1973/74 (Graph 3.7).

iii) The 'profit margin' or difference between sales value per unit and total cost appears to have narrowed over the whole period (Graph 3.7). Although the difference in slopes of the best fitting experience curves for each of sales value and total cost per unit is not statistically significant (3.4.1 (a)), additional analysis of annual profit margin shows a significant linear trend.

The decline in profit margin per unit is estimated to be approximately 5.5% p.a. (See 3.4.1 (b)), (Graph 3.8).

iv) Fixed cost per unit is declining (experience curve slope 76%), but direct cost per unit shows no statistically significant trend (3.4.1 (c)). It has increased over the periods 1968/69 to 1972/73 and 1973/74 onwards (Graph 3.9).

v) Data for MIG rectifiers shows a decline both in sales value per unit and direct cost per unit. The latter declines very steadily from 1969/70 onwards (Graph 3.10).

vi) Data for TIG rectifiers shows extreme swings in both sales value per unit and total cost per unit over the period (Graph 3.11).

3.5 Conclusions

a) The experience curve model fits data for all rectifiers for sales value per unit, total cost per unit and the component part of total cost formed by fixed costs per unit.

Direct cost per unit is not fitted by an experience curve model, and appears to have no significant trend over the period 1965/66 to 1976/77.

Data for TIG rectifiers, either sales value per unit or total cost per unit, is not fitted by an experience curve model.

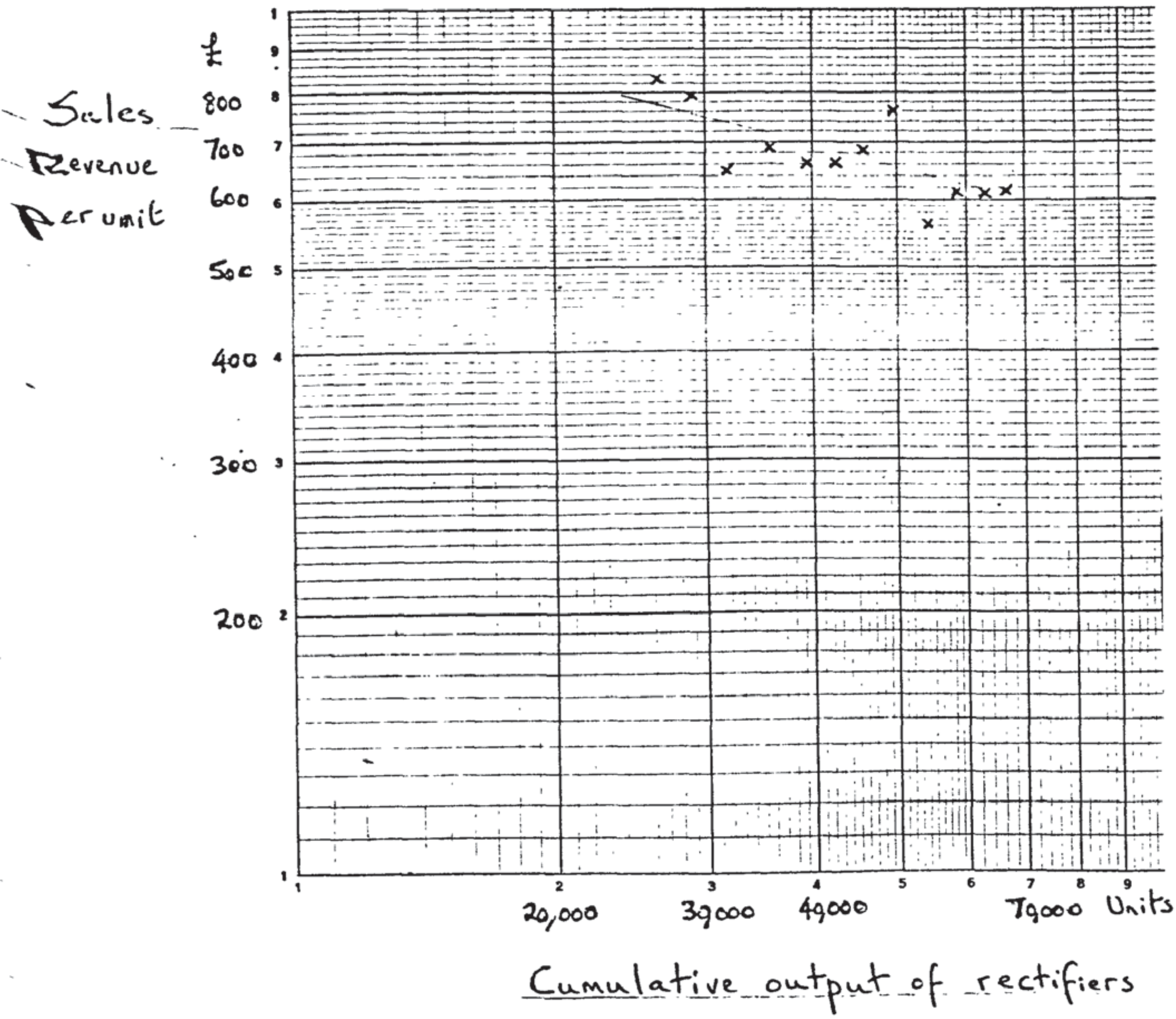
b) The narrowing gap between sales value and total cost per unit, for all rectifiers, with resulting decline in 'profit margins' could be due to the following causes:

i) The lack of reduction in direct cost per unit, for rectifiers as a whole.

ii) The behaviour of sales value per unit and total cost per unit of TIG rectifiers.

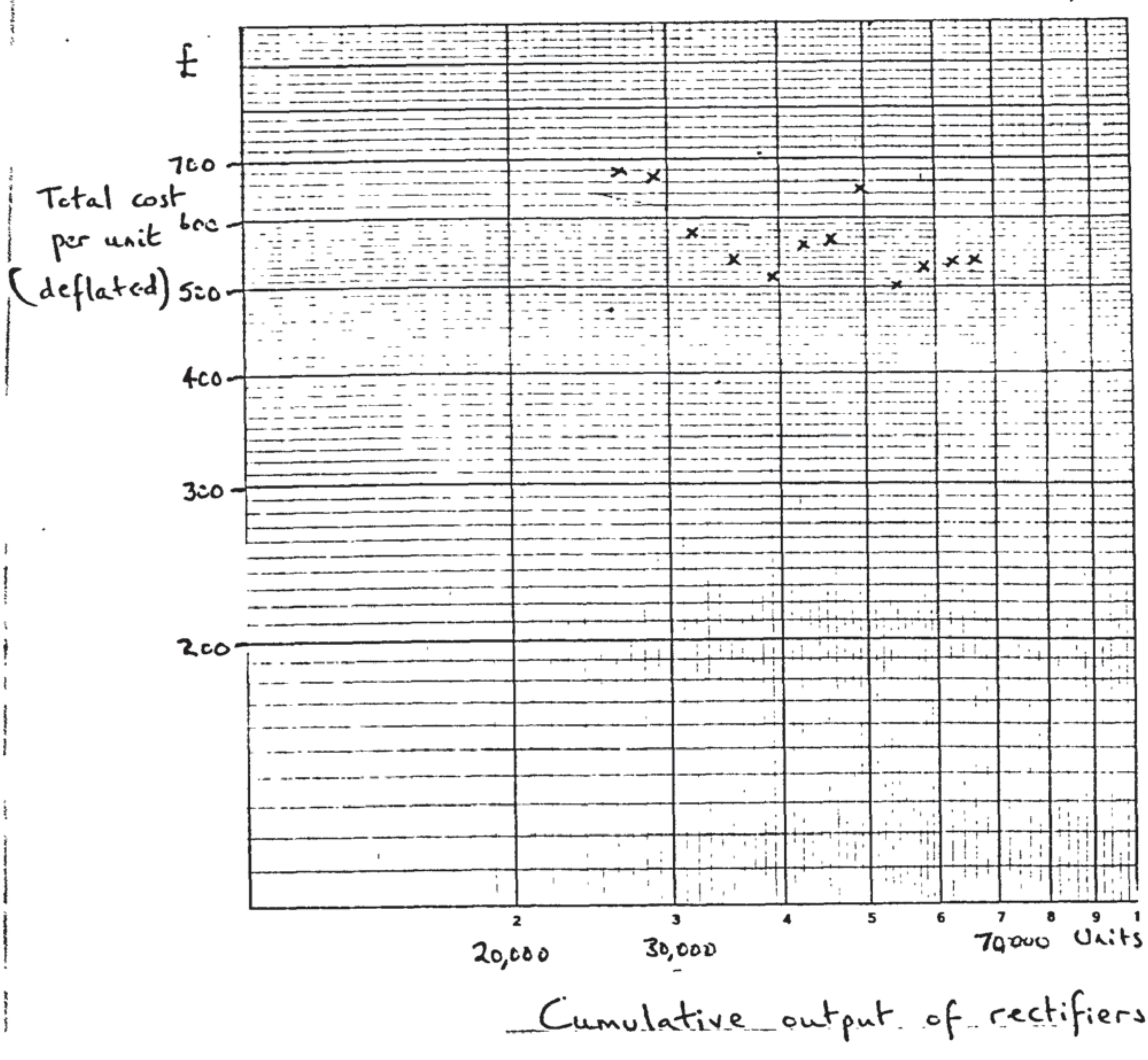
Graph C 3.1 BOC AE and HWR, joint business; overall decline in sales revenue per unit 1966-77

Graph 3.1

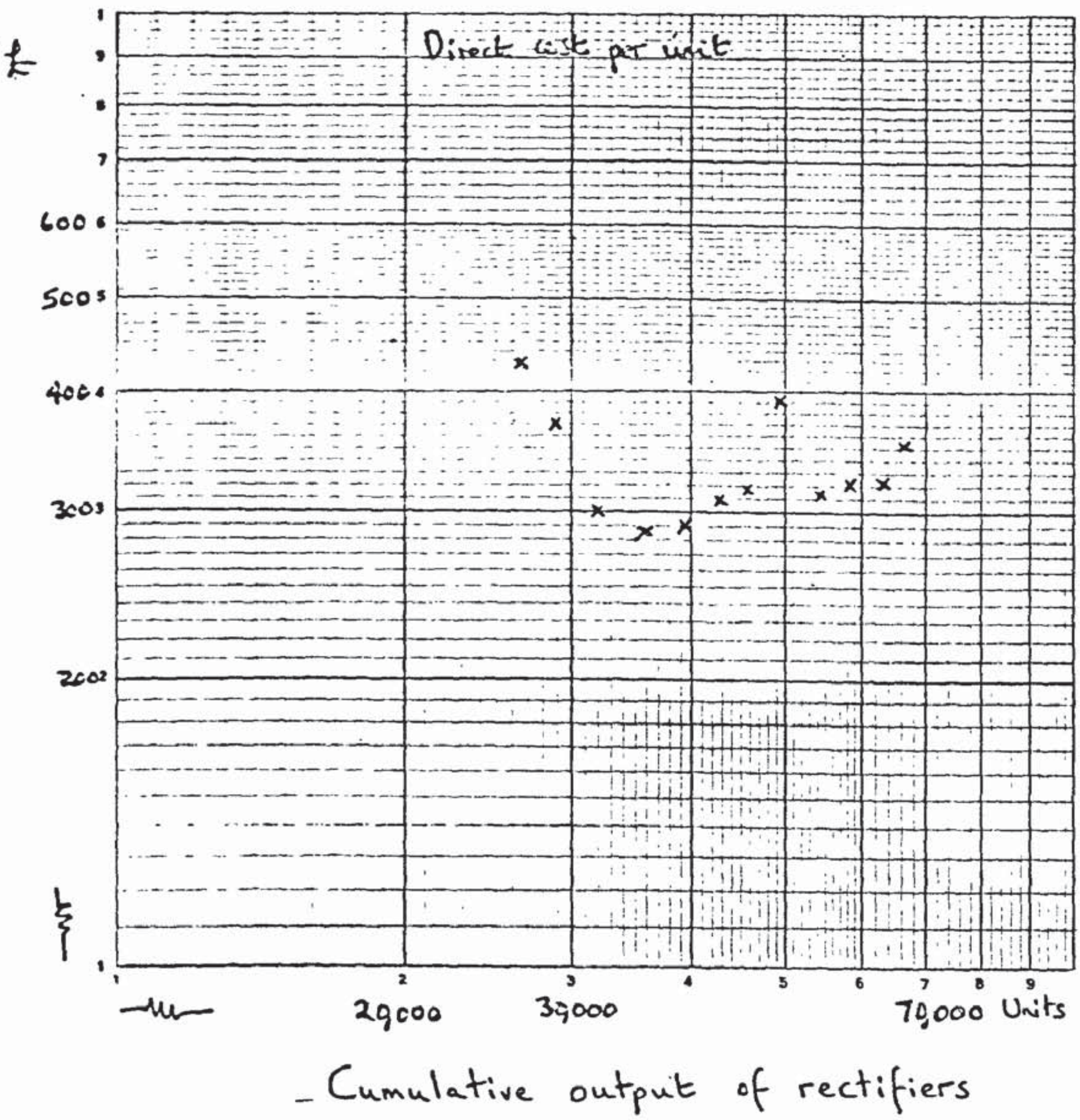


Graph C 3.2 BOC AE and HWR, joint business; overall decline in total cost per unit 1966-77

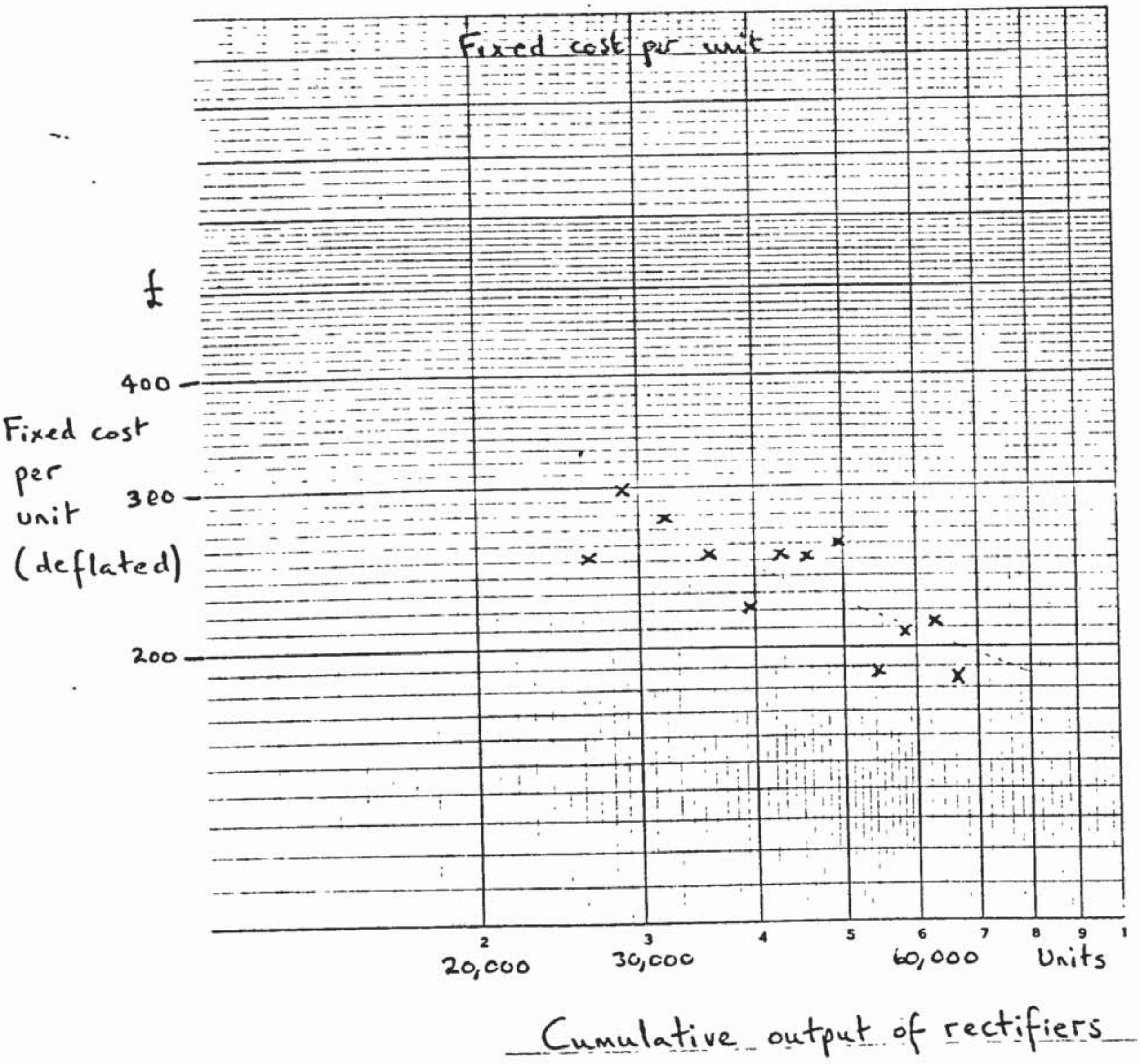
Graph 3.2



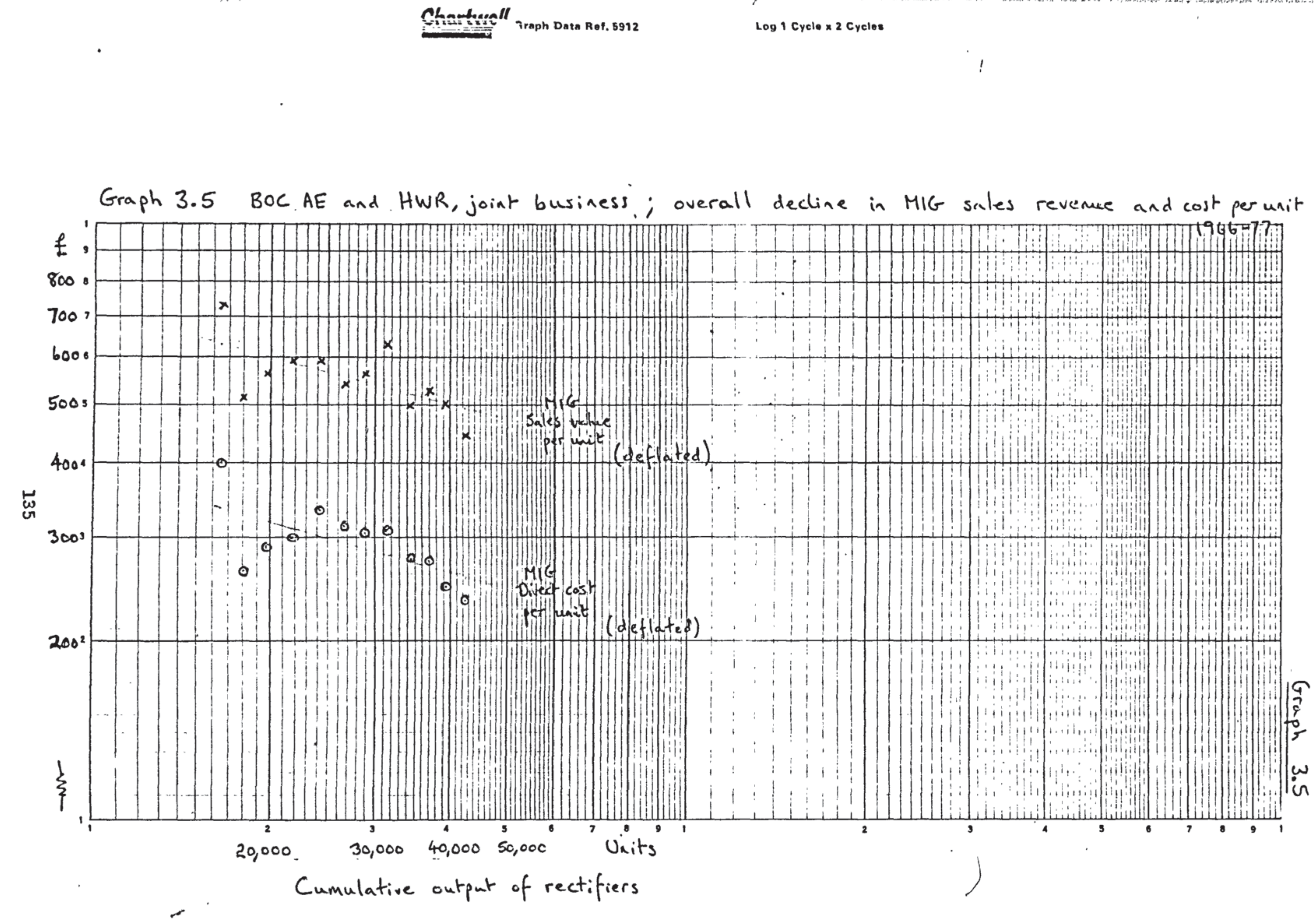
Graph C 3.3 BOC AE and HWR, joint business; no overall trend in direct cost per unit 1966-77



Graph C 3.4 BOC AE and HWR, joint business; overall decline in fixed cost per unit 1966-77

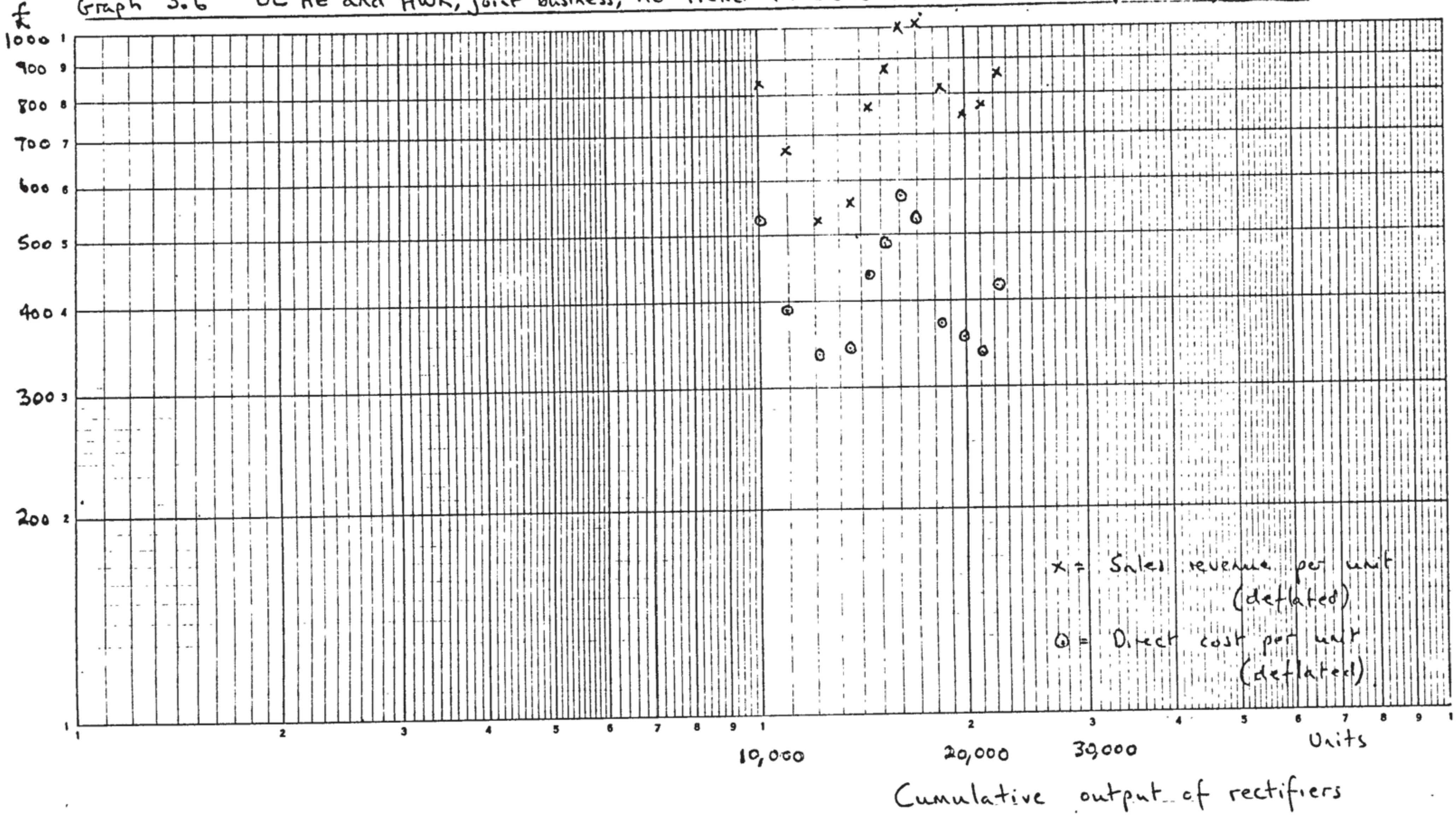


Graph 3.5 BOC AE and HWR, joint business; overall decline in MIG sales revenue and cost per unit 1966-77



Chartwell Graph Data Ref. 5912 Log 1 Cycle x 2 Cycles

Graph 3.6 OC AE and HWR, joint business; no trend in sales revenue or cost per unit, 1966-77

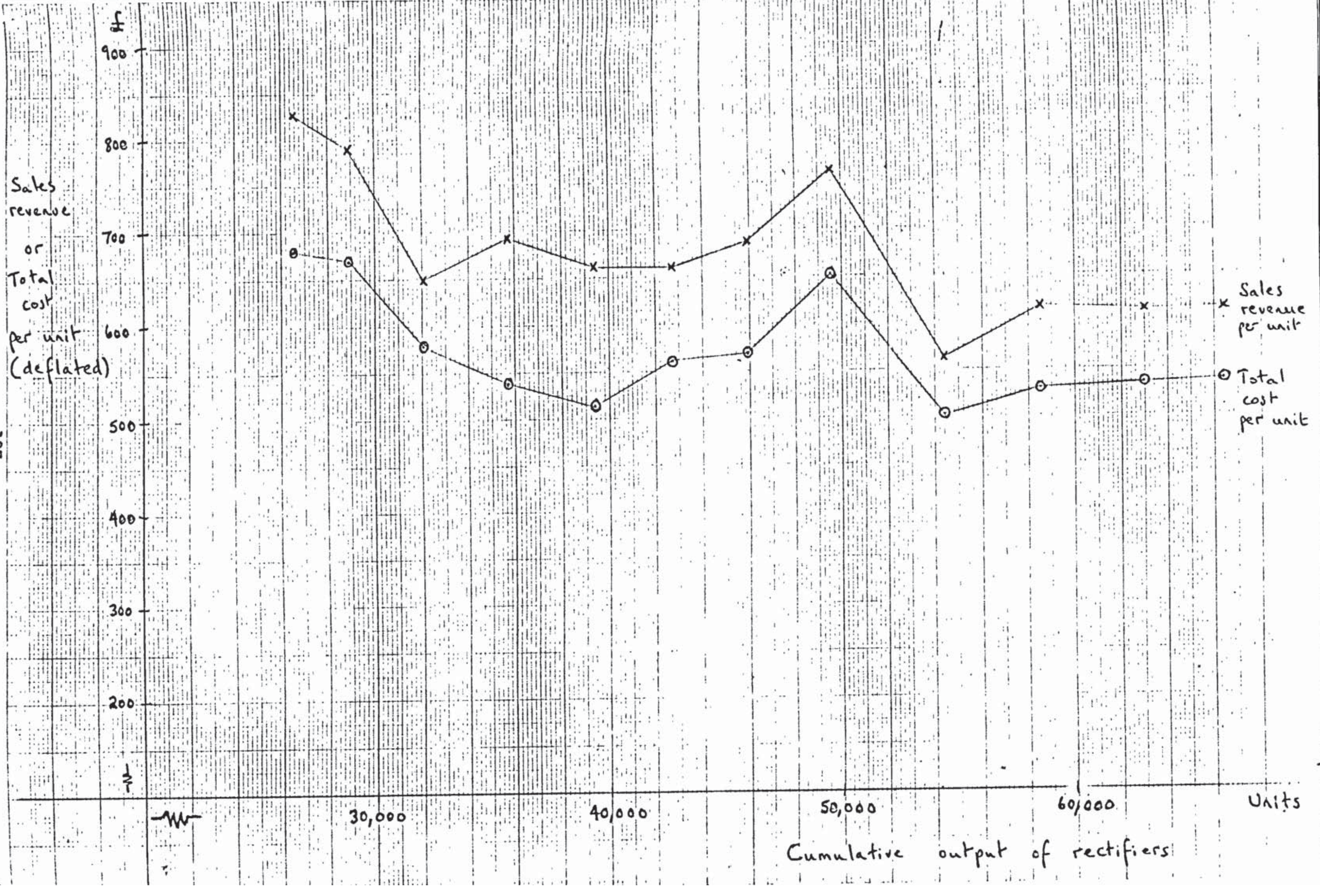


Graph 3.6

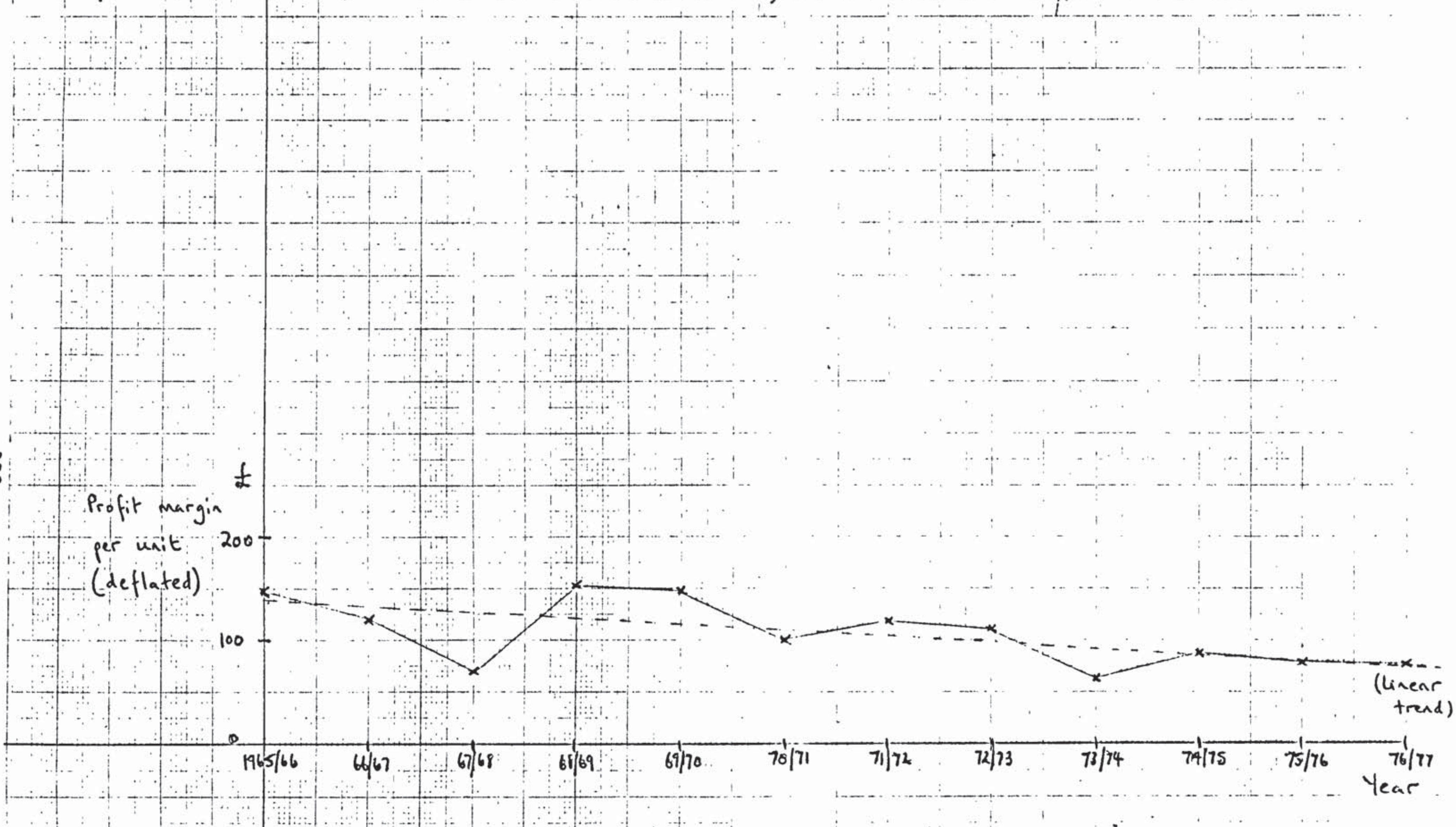
TEXT BOUND INTO

THE SPINE

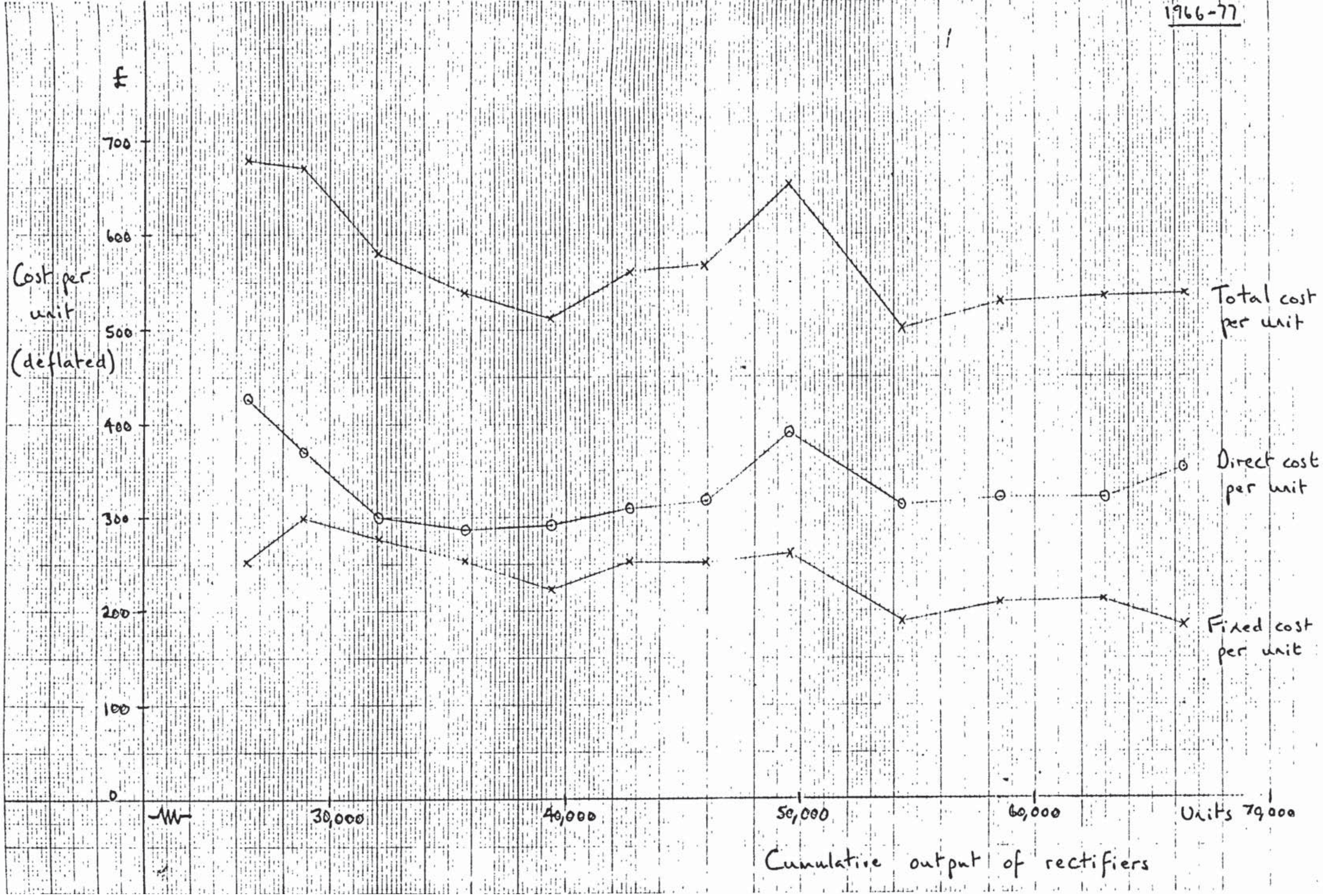
Graph C.3.7 Comparison between sales revenue per unit and total cost per unit, 1966-77



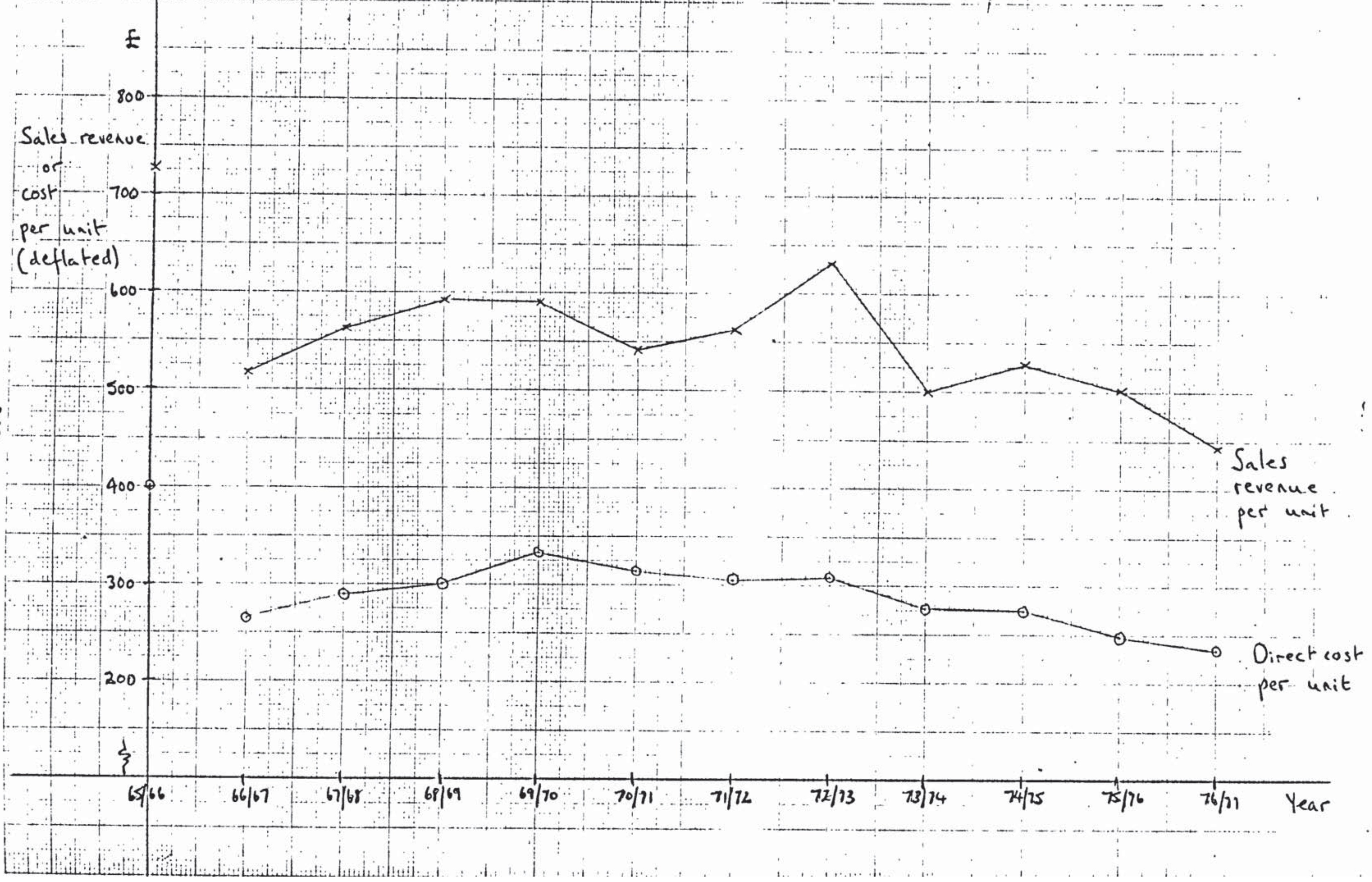
Graph C.3.8 BOC AE and HWK, joint business: Profit margin per unit (difference between sales revenue and total cost, per unit) declines over the period 1966-77

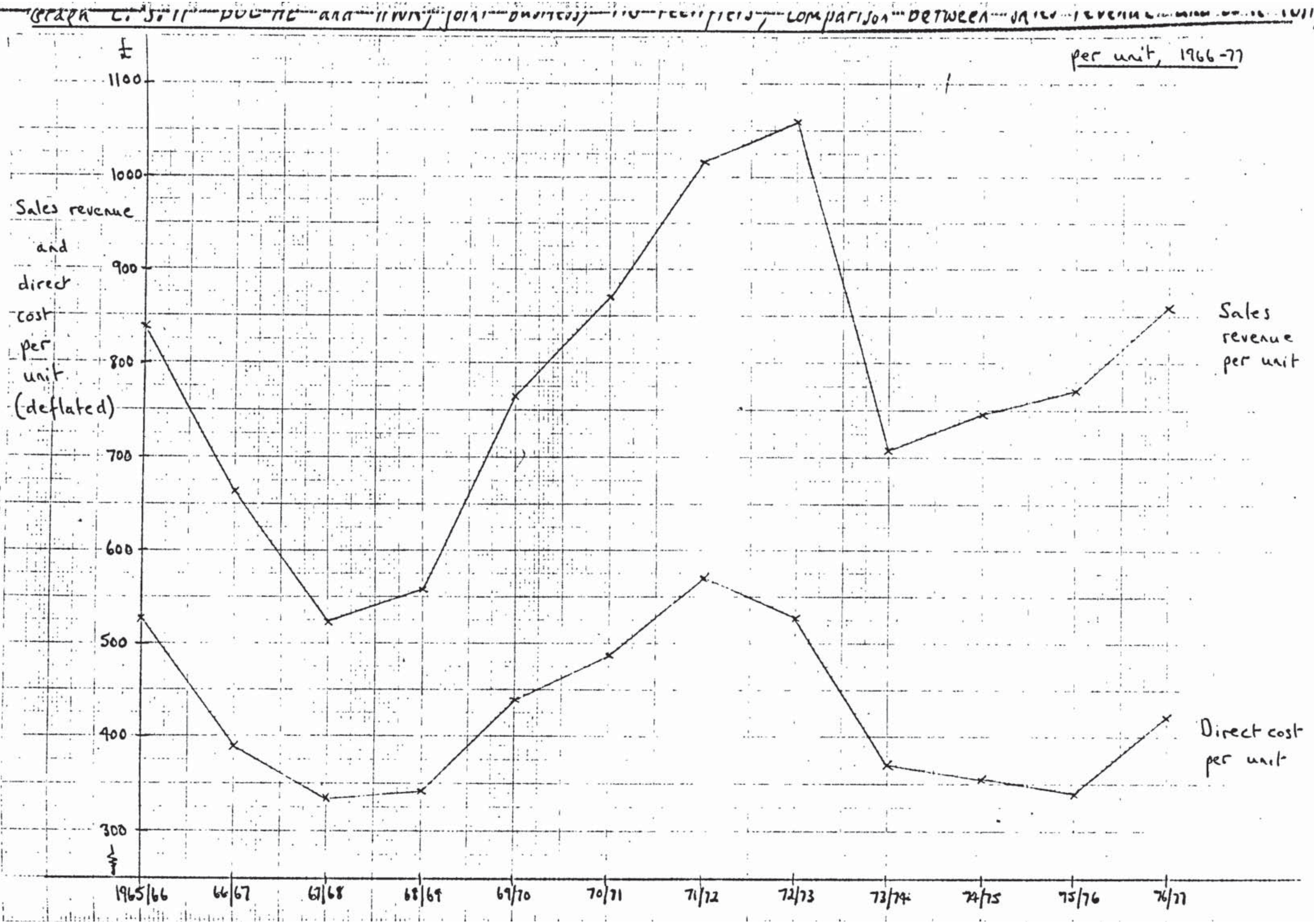


Graph 3.4 BOC AE and HWK, joint business, comparison of total cost, direct cost, and fixed cost, per unit 1966-77



Graph C.5.10 BSC AE and HWK, joint business, MIG rectifiers, comparison between sales revenue and direct cost per unit, 1966-77




per unit, 1966-77
£
1100
1000
900
800
700
600
500
400
300
Sales revenue and direct cost per unit (deflated)
Sales revenue per unit
Direct cost per unit
1965/66
66/67
67/68
68/69
69/70
70/71
71/72
72/73
73/74
74/75
75/76
76/77

Appendix C

4. Confidence limits for slope of experience curve model

Theory

If equation of underlying model is

$c = aV^{-b}$

where c = cost or average price per unit

V = cumulative output in units

a,b are parameters of the model,

then i) $\log c = \log a - b \log V$

expresses a linear relationship which may be tested using linear regression techniques,

and ii) the slope of the curve is calculated from the value of the parameter b:

'Slope' = $\frac{1}{2^b}$, usually expressed as a percentage.

If linear regression is used to find the best straight line through data for log c and log V, a sample estimate, $\underline{b}$ say, is found for the parameter b.

Confidence limits for the slope of the curve may be calculated from confidence limits for $\underline{b}$.

These are estimated using the sample estimate $\underline{b}$ and its variance, $\underline{\sigma_b^2}$ say.

If the variance of error of the original model is σ^2,

$$\underline{\sigma_b^2} = \frac{\sigma^2}{\sum(x - \bar{x})^2} \qquad \text{where } x = \log V$$

This may be estimated using the sample estimate S^2 for σ^2,

$$S^2 = \frac{\sum (y - \hat{y})^2}{n-2} \qquad \text{where } y = \log c$$

n = number of

$\hat{y}$ = value of y estimated from fitted model readings

Now $F = \dfrac{\text{Regression Mean Square}}{\text{Residual Mean Square}}$

$$= \frac{\underline{b}^2 \sum (x - \bar{x})^2}{(y - \hat{y})^2} (n-2)$$

$$\therefore \quad S^2 = \frac{\underline{b}^2 \sum (x - \bar{x})^2}{F}$$

$$\text{and } \underline{\sigma_b^2} = \frac{S^2}{\sum (x - \bar{x})^2} = \frac{\underline{b}^2}{F}$$

i.e. $\underline{\sigma_b}$ is estimated by $\dfrac{\underline{b}}{\sqrt{F}}$

Then confidence limits for the true value of b are given by

$$\underline{b} \pm t_\alpha \underline{\sigma_b}$$

where α depends on the level of confidence required.

Throughout this exercise α is taken to be 0.05, which gives 95% confidence limits.

4.1 BEAMA data for average price of a rectifier from subscribing companies.

The best straight line through data for log deflated average price and log cumulative output is given by

$y = 3.958 - 0.302x$,

with $r = -0.89$, $F = 48.3$, number of data points = 15 (Appendix C.2, Table 2.7).

The sample estimate of 0.3023 for b gives experience curve slope of 81.1%.

Confidence limits for b are given by

$$-0.3023 \pm t_{0.5} \times \frac{b}{\sqrt{F}}$$

(with number of degrees of freedom = 13)

$= -0.3023 \pm 2.16 \times 0.0435$

$= -0.2083, -0.3963$

Giving experience curve slope of 86.6%, 76.0%.

4.2 BEAMA data for average price of a rectifier for BOC Arc Equipment.

The best straight line through data for the log of deflated average price and log of cumulative output is given by

$y = 3.7576 - 0.2800x$

with $r = -0.77$, $F = 19.4$, number of data points = 15 (Appendix C.2, Table 2.7).

The sample estimate of 0.2800 for b gives experience curve slope of 82.4%.

95% confidence limits for b are given by

$-0.2800 \pm t_{0.5} \times \frac{b}{\sqrt{F}}$ (with 13 d.f.)

$= -0.2800 \pm 2.16 \times 0.0636$

$= -0.1426, -0.4174$

Giving experience curve slopes of 90.6%, 74.9%.

4.3 <u>BOC Arc Equipment data for sales revenue per unit for numbers of rectifiers produced.</u>

The best straight line through data for log sales revenue per unit and log cumulative output is given by

$y = 4.074 - 0.268x$

with $r = -0.72$, $F = 10.7$, number of data points = 12 (Appendix C.3, Table 3.11).

The sample estimate of 0.268 for b gives an experience curve slope of 83.0%.

Confidence limits for b are given by

$-0.268 \pm t_{0.5} \times \frac{b}{F}$ (10 degrees of freedom)

$= -0.268 \pm 2.23 \times 0.08193$

$= -0.0853, -0.4507.$

Giving experience curve slopes of 94.3%, 73.2%.

4.4 BOC Arc Equipment data for total cost per unit for numbers of rectifiers produced.

The best straight line through the data is given by

$y = 3.721 - 0.208x$

with $r = -0.61$, $F = 6.03$, number of data points = 12

(Appendix C.3, Table 3.11).

The sample estimate of 0.208 for b gives an experience curve slope of 86.5%.

Confidence limits for b are given by

$$-0.208 \pm t_{0.5} \frac{x\ b}{\sqrt{F}} \qquad \text{(10 degrees of freedom)}$$

$$= -0.208 \pm 2.23 \times 0.0847$$

$$= -0.0191, -0.3969,$$

Giving experience curve slopes of 98.7%, 75.9%.

APPENDIX D

Analyses to test a variety of data for alternative models for unit cost or average price of the product concerned

Index

1.4 <u>Results and Conclusions</u>

2. <u>Measurement of error of fit</u>

3. <u>Estimates of accuracy of prediction for models for UK industry average price and BOC Arc Equipment unit cost</u>

3.1 Results for model for unit cost for BOC Arc Equipment

3.2 Results for model for average price of a rectifier in the UK industry

3.3 Summary and conclusions

4. <u>Analyses relating to the experience curve model</u>

4.1 Comparison of experience curve 'slopes' from models fitted to different sets of data

4.2 Investigation of the coincidence of trends in price or unit cost behaviour with periods of differing market growth rates

APPENDIX D Index to tables

Appendix D: Analyses to test a variety of data for alternative models for unit cost or average price of the product concerned

Data was obtained from BOC Arc Equipment, from arc welding equipment industries of various countries, including the UK, and from manufacture of other products. The usable sets of data were then tested for the fit of the experience curve and alternative models.

Results were collated and analysed to establish whether one model universally gave the best fit to all sets of data. This proved not to be true, and a measure of the error of fit was calculated for each model significantly fitting each set of data. The penalty of choosing one uniform model, over the best-fitting model for each case, was measured by the percentage worsening of the error of fit thus obtained.

In order to be able to recommend the best fitting models for BOC AE and the UK industry, additional analyses compared errors of fit obtained from fitting different forms of the model on this data. Also, in the case of BOC AE, further work was required to test the effect of errors in predicted volumes of output on the accuracy of a volume-related model. Confidence limits for the accuracy of prediction of unit cost and average price from these models were estimated and compared.

Further analyses were designed to investigate general claims made about the experience curve model, that of a general band of slopes (70-90%) for manufacturing operations, and also the link between high market growth rate and the slope of the model fitting data in these conditions.

The appendix is in three sections. Section 1 contains the collection and analyses of data for testing alternative models. Section 2 covers the additional analyses required for comparing errors of fit, and section 3 the work covering specific claims for the experience curve model.

D.1 Collection of data, analysis and results

General remarks on data sources and methods used in the analysis are followed by the details of tests on each set of data.

Sources of data

These included government trade statistics, (mostly found at Warwick University Library), EEC NIMEXE data on imports and exports, obtained from the European Communities Information Service, welding trade associations, publications, and journals, BOC Arc Equipment and other BOC companies .

Details of the source, type of data, category of product to which it refers, and the data itself are given under the heading of the country or product.

Thirty-two sets of data were collected, of which eighteen were used in the final analysis. Fourteen were discarded after initial analyses and plotting of graphs, either due to the inadequate number of data points, or obvious inconsistency in the data, or both.

Almost all of the data consisted of annual volumes and values of sales, sometimes with annual cost figures.

Methods used in analyses

Value of sales or cost data was divided by the appropriate volume of output to give average price or unit cost which was then deflated using an appropriate index, and became the dependent variable in all models tested.

Independant variables tested included cumulative output, volume of output (annual), and elapsed time measured in years. Cumulative output for the beginning of the period covered by the data was usually estimated using the method described in Appendix C, 2.1.2 (c). In the cases where volume growth was negative over the period in question, the average output volume was multiplied by the estimated number of previous years of production.

Models tested were log/log, log/linear and linear sometimes extended to include more than one independent variable; the forms of the models and the techniques of linear regression analysis used in the tests are described in Appendix B (B.1)

Since all sets of data could not be tested with all possible models in the time available, tests were selective and done in the following order:

i) All sets of data were plotted on a graph, and tested for the experience curve model, ie. a significant relationship between the dependent variable and cumulative output, using a log/log form.

ii) If results of (i) proved positive, data was tested using a multiple regression test of a linear relationship between the dependent variable and each of cumulative output, annual volume of output, and elapsed time, as independent variables.

As well as exposing correlations with the other independent variables, this made possible the comparison of linear and log/log models for the relationship with cumulative output.

At the same time, data was tested for the inclusion of more than one variable in the model.

iii) If results of (i) proved negative, data or graphs were inspected for visual signs of a relationship between the dependent variable and volume of output. If suspected, this was tested using linear regression analysis.

It must be noted that, since each of elapsed time and cumulative output are monotonically increasing, they are bound to be highly correlated with each other. This was supported by the results of multiple regression analysis. Thus, if the dependent variable was not correlated with cumulative output, it was unlikely to be correlated with elapsed time, and therefore the latter relationship was not tested.

iv) In the case of BOC AE and UK industry data, tests include the log/linear model, and multiple regression analysis testing each form of the model on all sets of variables.

In addition, partial regression analysis was used to find the extent to which correlation between the dependent variable and one particular independent variable was due to correlation between the latter and another independent variable. eg. If average price was correlated with cumulative output, to what extent was this due to the correlation between cumulative output and elapsed time?

Results of the main analyses fitting alternative models to available sets of data are summarised in Tables D.30 and 31

Details of each analysis are given below, in sections categorised by the type of data included.

BOC Arc Equipment and BEAMA data for the UK industry, in 1.1, data from arc welding equipment industries of other countries, in 1.2, and from other UK manufacturers, in 1.3.

D.1.1 Data from BOC Arc Equipment and BEAMA (Includes data for the UK industry)

Summary of results (Tables D.1-D.3), data (Tables D.4 and D.5) and graphs D.1 to D.4 are given at the end of this section. (Page 170)

1.1.1 UK arc welding equipment industry (as represented by members of BEAMA)

Data

(see Table D.4) Details of source and data appear in Appendix C,2.1. Briefly, data consisted of value and volume of rectifier sales aggregated from all subscribing members to BEAMA, the British Electrical and Allied manufacturers association, and was available for 1962 onwards. Deflating index; The index of Home Sales of Manufactured Goods (UK).

Results

(see Graph D.1) It was already known that average price was significantly correlated with cumulative output. (see Appendix C,2.2 Table 2.7).

Multiple regression tests showed the following:

a) Linear model

$$y = a_1x_1 + a_2 x_2 + a_3 x_3 + a_4$$

where y = average price of a rectifier (deflated)

x_1 = elapsed time in years

x_2 = annual volume of output

x_3 = cumulative output

$a_1..a_4$ are parameters of the model

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.913	1.0		
x_3	0.987	0.728	1.0	
y	-0.896	-0.893	-0.916	1.0

Individual regressions on x_1, x_2, x_3.

Regressions on x_3; R^2 = 83.9%, significant at 0.1%
" " x_1; R^2 = 80.3%, " " 0.1%
" " x_2; R^2 = 79.7%, " " 0.1%

Inclusion of a further variable with x_3 did not significantly improve the fit of the model.

b) Log/Linear model

$$y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

x_1, x_2, x_3, y, $a_1 \ldots a_4$ as in (a).

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.908	1.0		
x_3	0.957	0.925	1.0	
y	-0.829	-0.885	-0.894	1.0

Individual regressions on x_1, x_2, x_3.

Regressions on x_3; R^2 = 79.9%, significant at 0.1%

" " x_1; R^2 = 68.7%, significant at 0.1%

" " x_2; R^2 = 78.3%, significant at 0.1%

c) Log/Log model

$$\text{Log } y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

x_1, x_2, x_3, y, $a_1 \ldots a_4$ as in (a)

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.908	1.0		
x_3	0.957	0.925	1.0	
y	-0.806	-0.875	-0.891	1.0

Individual regressions on x_1, x_2, x_3.

Regressions on x_3; R^2 = 79.4%, significant at 0.1%

" " x_2; R^2 = 76.5%, significant at 0.1%

" " x_1; R^2 = 65.0%, significant at 0.1%

The inclusion of a further variable in a model with x_3 did not significantly improve the fit of the model.

d) Partial correlation analysis

Notation: If $r$ab is the correlation coefficient for correlation between variables a and b, $r$ab,c is the coefficient denoting correlation between a and b if that part of the correlation between a and b if the effect due to correlation between b and c is removed.

$r$ab,c is calculated by subtracting a proportion of the correlation between c and a from the correlation between b and a, the proportion being the correlation between b and c. The result is then scaled up using a factor depending on $r$ab and $r$bc.

$$ab,c = \frac{r_{ab} - r_{ac} \cdot r_{bc}}{\sqrt{(1 - r^2_{ac})(1 - r^2_{bc})}}$$

This result can be extended to the removal of the effects of a further independent variable.

Results for aggregated BEAMA data

Results from the Linear model were used for analysis since these gave the highest correlation coefficients for individual regressions.

coefficients for remaining correlation between each of the three independent variables elapsed time (variable 1) volume of output (variable 2) cumulative output (variable 3) and the dependent variable (variable 4), if the effect of other correlations are removed, are given below.

	Correlation of each independent variable with average price		
	Time	Volume	Cumulative Output
Original correlation Coefficients Significance levels	r_{14} -0.896 0.1%	r_{24} -0.893 0.1%	r_{34} -0.916 0.1%
Correlation with one variable removed	$r_{14,2}$ $r_{14,3}$ -0.429 -0.205	$r_{24,1}$ $r_{24,3}$ -0.343 -0.322	$r_{34,1}$ $r_{34,2}$ -0.038 -0.436
Correlation with two variables removed	$r_{14,32}$ -0.048	$r_{24,13}$ -0.303	$r_{34,12}$ -0.099

This shows that correlation between average price and each of elapsed time and cumulative output are virtually indistinguishable, since each is reduced almost to nothing if the effect of correlations between the independent variables is removed. It also shows that there is some correlation between average price and output volume, independent of correlations between output volume and either of cumulative output or elapsed time.

1.1.2 <u>BOC Arc Equipment data for average price</u>

<u>Data</u> (See Table D.5)
Details of source and adjustment to data can be found in Appendix C.3.2. Briefly, the data consists of annual sales revenue and costs of producing and marketing MIG and TIG welding equipment, and volume of output of MIG and TIG rectifiers, available from 1965/66 onwards. (NB TIG data includes that for DC Manual rectifiers and Plasma welding machines).

<u>Deflating Index</u>;
The index used was the Home Sales of all manufactured goods(UK).

<u>Results</u>
It was already known that average price per unit was significantly correlated with cumulative output in the log/log model.
(See Appendix C.3.4 Table 3.11)

Graphs D.2 and D.3 show unit price plotted against each of elapsed time, output volume, and cumulative output, on a linear scale.

Multiple regression tests showed the following:

a) Linear model

$$y = a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4$$

where y = average price per unit

x_1 = elapsed time in years

x_2 = annual volume of output

x_3 = Cumalative output

$a_1 \ldots a_4$ are parameters of the model.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.835	1.0		
x_3	0.998	0.833	1.0	
y	-0.713	-0.841	-0.707	1.0

Individual regressions on x_1, x_2, x_3.

x_2 : R^2 = 70.8%, significant at 0.1%

x_1 : R^2 = 51.3%, " " 1.0%

x_3 : R^2 = 50.0%, " " 2.5%

The inclusion of a further variable with x_2 did not significantly improve the fit of the model.

b) Log/linear model

$$y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

x_1, x_2, x_3, y, $a_1 \ldots a_4$ as in (a). above.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.864	1.0		
x_3	0.963	0.856	1.0	
y	-0.773	-0.847	-0.732	1.0

Individual regressions on x_1, x_2, x_3

x_2 : R^2 = 71.[illegible]%, significant at 0.1%

x_1 : R^2 = 59.7%, significant at 1.0%

x_3 : R^2 = 53.6%, significant at 1.0%

Inclusion of a further variable with x_2 did not significantly improve the fit of the model.

c) Log/log model

$$\log y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

x_1, x_2, x_3, y, $a_1 \ldots a_4$ as in (a) above.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.845	1.0		
x_3	0.999	0.858	1.0	
y	-0.719	-0.854	-0.734	1.0

Individual regressions on x_1, x_2, x_3

x_2 : R^2 = 73.0%, significant at 0.1%

x_1 : R^2 = 51.7%, " " 1.0%

x_3 : R^2 = 53.9%, " " 1.0%

Inclusion of a further variable in a model with x_2 did not significantly improve the fit of the model.

d) Results of partial correlation analysis

(See 1.1.1 (d) for explanation of method)

Variable 1 = Elapsed time

" 2 = Annual volume of output

" 3 = Cumulative output

" 4 = Average sales revenue per unit

NB ab,c denotes the correlation remaining between variables a and b if the effect due to correlation between b and c is removed.

	Correlation between each indep variable and sales revenue per unit					
	Time		Volume		Cum. output	
Original coeffs (log/log model) significance levels	r_{14} -0.719 1.0%		r_{24} -0.854 0.1%		r_{34} -0.734 1.0%	
Correlation with one variable removed Sig levels	$r_{14,2}$ +0.009 not sig at 5%	$r_{14,3}$ +0.47 	$r_{24,1}$ -0.66 2.5%	$r_{24,3}$ -0.64 2.5%	$r_{34,1}$ 0.51 not sig at 5%	$r_{34,2}$ -0.005
Correlation with effects of two variables removed	$r_{14,23}$ +0.183 not sig at 5%		$r_{24,13}$ -0.524 not sig at 5%		$r_{34,12}$ -0.182 not sig at 5%	

This analysis shows that the correlation between volume and sales revenue per unit has a large element which is independent of correlations between volume and either cumulative output or elapsed time.

Although initially there appear to be strong correlations between each of elapsed time and cumulative output, and sales revenue per unit, these are reduced almost to zero if secondary correlations with output volume are removed.

1.1.3 BOC Arc Equipment data for unit cost

Data

See 1.1.2and Table D.5. Unit cost is the total cost of manufacture of MIG and TIG welding equipment (including DC Manual and Plasma), divided by the number of rectifiers produced.

Deflating Index;

Home Sales of all manufactured goods (UK).

Results

It was already known that average cost per unit was correlated with cumulative output in the log/log model. (See Appendix C.3.4 Table 3.11). Graph D.4 shows the results of plotting unit cost against each independent variable, on a linear scale.

Multiple regression analysis showed the following:

a) Linear model

$$y = a_1 x_1 + a_2 x_2 + a_3 x_3 + a_4$$

where y = average total cost per unit

x_1 = elapsed time in years

x_2 = volume of output (annual)

x_3 = Cumulative output

$a_1 \ldots a_4$ are parameters of the model.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.835	1.0		
x_3	0.998	0.833	1.0	
y	-0.592	-0.790	-0.585	1.0

Individual regressions on x_1, x_2, x_3

x_2 : R^2 = 62.4%, Significant at 1.0%

x_1 : R^2 = 35.1%, " " 5.0%

x_3 : R^2 = 34.2%, " " 5.0%

The inclusion of a further variable with x_2 did not significantly improve the fit of the model.

b) Log/linear model

$$y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

x_1, x_2, x_3, y, $a_1 \ldots a_4$ as in (a) above.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.864	1.0		
x_3	0.963	0.856	1.0	
y	-0.693	-0.813	-0.624	1.0

Individual regressions on x_1, x_2, x_3

x_2 : R^2 = 66.1%, Significant at 1.0%

x_1 : R^2 = 48.0% , " " 2.5%

x_3 : R^2 = 38.9%, " " 5.0%

The inclusion of a further variable with x_2 did not significantly improve the fit of the model.

c) Log/log model

$$\text{Log } y = a_1 \log x_1 + a_2 \log x_2 + a_3 \log x_3 + a_4$$

where x_1, x_2, x_3, y, $a_1 \ldots a_4$ are as in (a) above.

Correlation Table

	x_1	x_2	x_3	y
x_1	1.0			
x_2	0.845	1.0		
x_3	0.994	0.858	1.0	
y	-0.605	-0.819	-0.629	1.0

Individual regressions on x_1, x_2, x_3

x_2 : R^2 = 67.1%, significant at 1.0%

x_3 : R^2 = 39.6%, " " 5.0%

x_1 : R^2 = 36.6%, " " 5.0%

The inclusion of a further variable with x_2 did not significantly improve the fit of the model.

d) Partial correlation analysis

See 1.1.1 (d) for explanation of method.

Variable 1 = Elapsed time

Variable 2 = Volume of output

Variable 3 = Cumulative output

Variable 4 = Average cost per unit

	Correlation between each independent variable and average cost per unit					
	Time		Volume		Cum. output	
Original coefficients (log/log model) significance levels	r_{14} -0.605 5.0%		r_{24} -0.819 1.0%		r_{34} -0.629 5.0%	
Correlation with effect of one variable removed significance levels	$r_{14,2}$ +0.284 not sig at 5%	$r_{14,3}$ 0.672 2.5%	$r_{24,1}$ -0.723 1.0%	$r_{24,2}$ -0.699 2.5%	$r_{34,1}$ -0.691 2.5%	$r_{34,2}$ 0.279 not sig at 5%
Correlation with effect of two other variables removed	$r_{14,32}$ 0.382 not sig at 5%		$r_{24,13}$ -0.552 not sig at 5%		$r_{34,12}$ -0.360 not sig at 5%	

This shows again that correlation between time and unit cost (as with unit price, see 1.1.2 (d)) has a large element independent of correlations between volume and each of elapsed time or cumulative output.

There is some correlation between time and unit cost independent of correlations between time and each of cumulative output or output volume, but correlation is positive. Correlation between cumulative output and unit cost is masked by the correlation with elapsed time which has an opposing effect, ie it is increased when the effect due to time is removed.

1.1.4 Summary

For tabulated results, see Table D.1 - D.3

a) BEAMA data, aggregated from all subscribers, for average price of a rectifier in the UK (See 1.1.1)

Average price of a rectifier was significantly correlated with each of elapsed time, annual volume of output, and cumulative output, in each form of the model tested.

Models relating average price to cumulative output explained the most variation in average price over the period of the data, and were significant at a higher level. This was true for each form of the model tested.

cumulative output. (R^2 = 0.84)

b) <u>BOC A.E data for average sales revenue per unit.</u> (See 1.1.2)

Average sales revenue per unit was significantly correlated with each of elapsed time, annual volume of output, and cumulative output, in each form of the model tested.

The independent variable which explained more variation in average price in any forms of the model tested, was that of annual output volume. (R^2 = 0.73)

The model explaining the most variation in sales revenue per unit was the log/log relationship with output volume. (See 1.1.2 (c))

In no case did inclusion of a further variable significantly improve the fit of the model.

c) <u>BOC AE data for average cost per unit</u> (See 1.1.3)

Again, average cost per unit was significantly correlated with each of the independent variables tested, although output volume explained more of the variation in average cost, in each form of the model tested.

The best model for explaining variation in average cost per unit over this period was a log/log relationship with output volume. (R^2 = 0.67)

Table D.1

Results of analyses of BEAMA data, aggregated data for UK companies

Independent variable	Form of model	Equation	R^2	F - ratio (sig level)
Cumulative output	Linear	y =525.38-0.003491x	0.84	67.72 (0.1%)
"	Log/ linear	y =1617.60-270.27logx	0.80	51.59 (0.1%)
"	Log/log	log y =3.958-0.3023logx	0.79	48.30 (0.1%)
Volume of output	Linear	y =539.68-0.03767x	0.80	51.03 (0.1%)
"	Log/ linear	y=1460.34-300.381logx	0.78	46.84 (0.1%)
"	Log/log	logy=3.7762-0.3343 logx	0.76	42.34 (0.1%)
Elapsed time	Linear	y = 504.81-13.331x	0.80	52:86 (0.1%)
"	Log/ linear	y = 529.33-162.39 logx	0.69	28.46 (0.1%)
"	Log/log	logy =2.7380-0.1779logx	0.65	24.16 (0.1%)

Table D.2

Results of analyses of BOC AE data for average price of a rectifier

Independent variable	Form of model	Equation	R^2	F - ratio (sig level)
Cumulative output	Linear	$y = 862.28-0.004185x$	0.50	10.00 (2.5%)
"	Log/linear	$y = 2701.03-436.208 \log x$	0.54	11.56 (1.0%)
"	Log/log	$\log y = 4.0742-0.2681 \log x$	0.54	11.69 (1.0%)
Volume of output	linear	$y = 1007.40-0.09195x$	0.71	24.25 (0.1%)
"	Log/linear	$y = 3282.84-734.669 \log x$	0.72	22.47 (0.1%)
"	Log/log	$\log x = 4.4645-0.4615 \log x$	0.73	27.04 (0.1%)
Elapsed time	Linear	$y = 1796.67-15.643\ x$	0.51	10.53 (1.0%)
"	Log/Linear	$y = 812.97-186.356 \log x$	0.60	14.85 (1.0%)
"	Log/log	$\log y = 5.7730 - 1.5886 \log x$	0.52	10.70 (1.0%)

Table D.3

Results of analyses of BOC AE data for average unit cost of a rectifier

Independent variable	Form of model	Equation	R^2	F - ratio (sig level)
Cumulative output	Linear	y = 692.335-0.002684x	0.34	5.20 (5.0%)
"	Log/ linear	y= 1911.38 - 288.822 log x	0.39	6.37 (5.0%)
"	Log/log	logy= 3.7213-0.2085 log x	0.40	6.56 (5.0%)
Volume of output	Linear	y = 809.44-0.0666x	0.62	16.60 (1.0%)
"	Log/ linear	y= 2514.57-547.920 logx	0.66	19.49 (1.0%)
"	Log/log	logy= 4.1767 - 0.4012 log x	0.67	20.39 (1.0%)
Elapsed time	Linear	y = 1288.50- 10.035x	0.35	5.41 (5.0%)
"	Log/ linear	y= 665.94-129.873 logx	0.48	9.25 (2.5%)
"	Log/log	y = 4.9945 - 1.2086x	0.37	5.77 (5.0%)

Table D.4

Aggregated data from BEAMA subscribers

Year	62/63	63/64	64/65	65/66	66/67	67/68
Average price (Deflated) £	507	493	414	394	427	447
Volume of output (unit)	1315	2153	2620	3010	2171	2633
Cumulative output (units) '000	13733	15886	18506	21516	23687	26320

Year	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Average price (Deflated) £	440	442	427	374	362	329	325	304	228
Volume of output (unit)	3541	4030	2800	3905	5782	5534	4880	5256	6729
Cumulative output (units) '000	29861	33891	36691	40596	46378	51912	56792	62048	68777

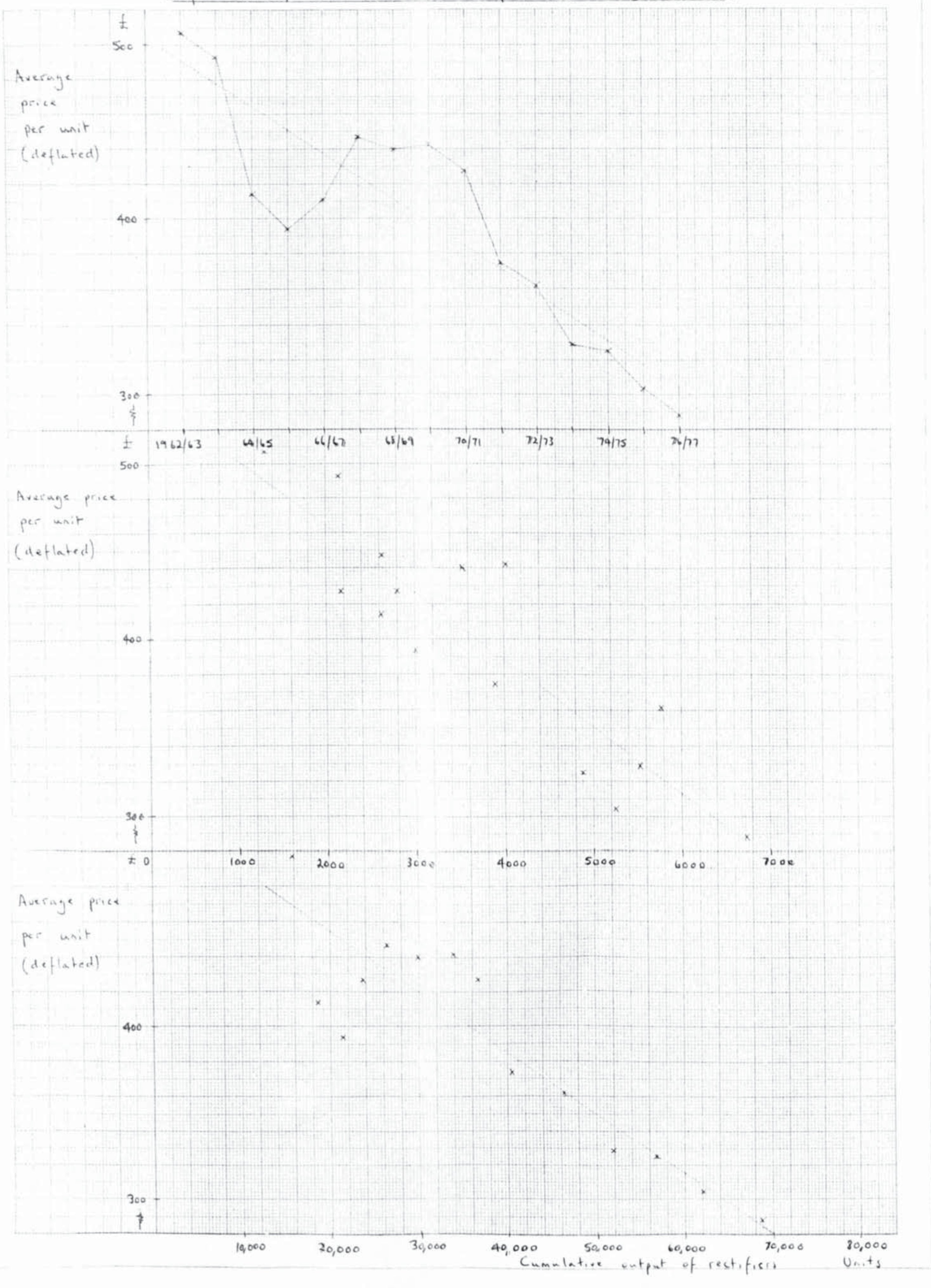
Table D.5

BOC Arc Equipment data submitted to BEAMA

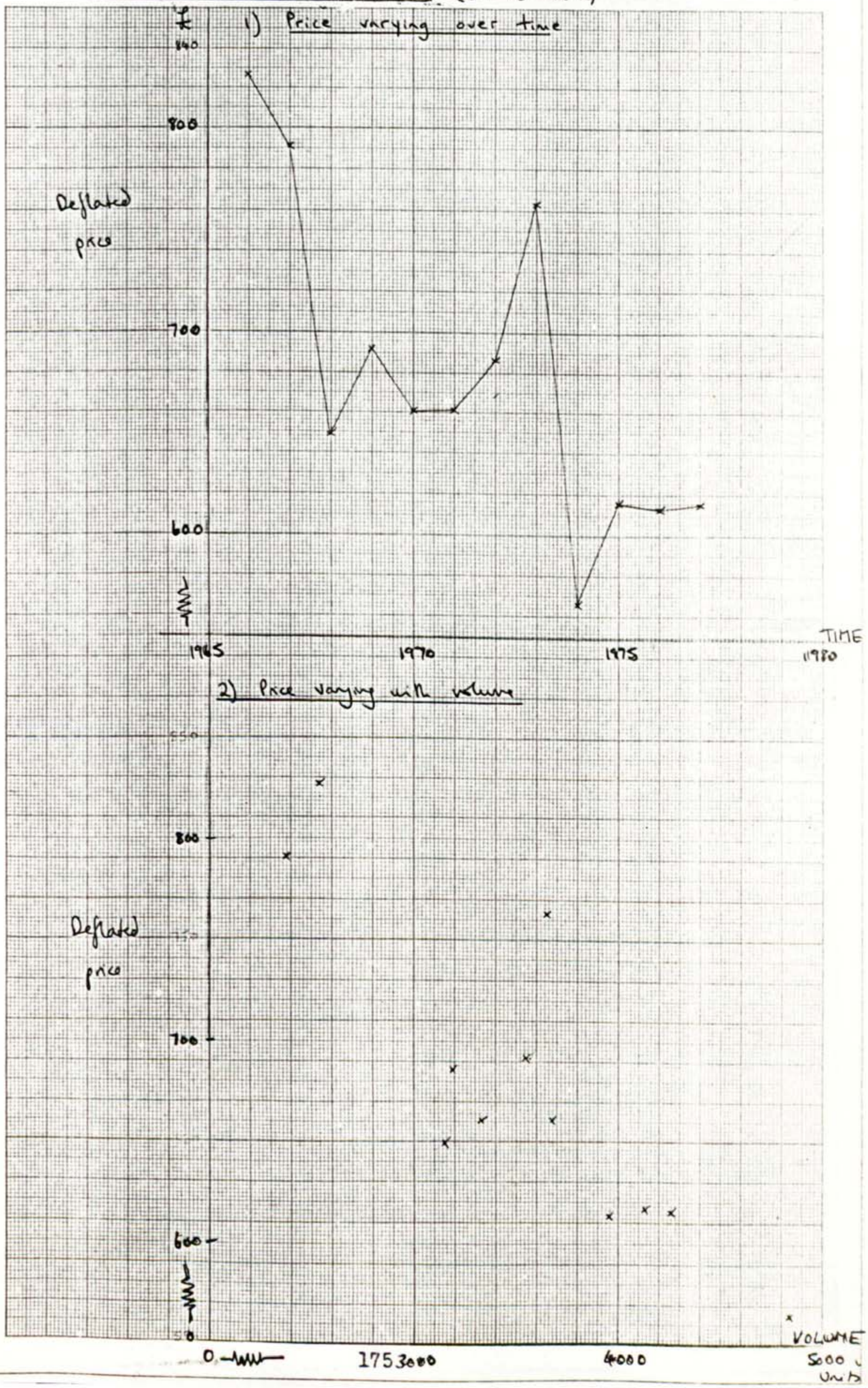
	65/66	66/67	67/68	68/69	69/70	70/71
Average price (Deflated) £	827	791	649	692	661	661
Average cost (Deflated) £	679	670	579	539	513	561
Volume of output (units)	2538	2378	3148	3653	3681	3335
Cumulative output (units)	26508	28886	32034	35687	39368	42703

	71/72	72/73	73/74	74/75	75/76	76/77
Average price (Deflated) £	686	763	564	616	613	615
Average cost (Deflated) £	568	652	501	529	535	538
Volume of output (units)	3187	3650	4842	4132	3960	4461
Cumulative output (units)	45890	49540	54382	58514	62974	66395

Graph D.1 Variation in average price of a rectifier (UK) with each of elapsed time, output volume, and cumulative output, 1963-77 (BEAMA data)

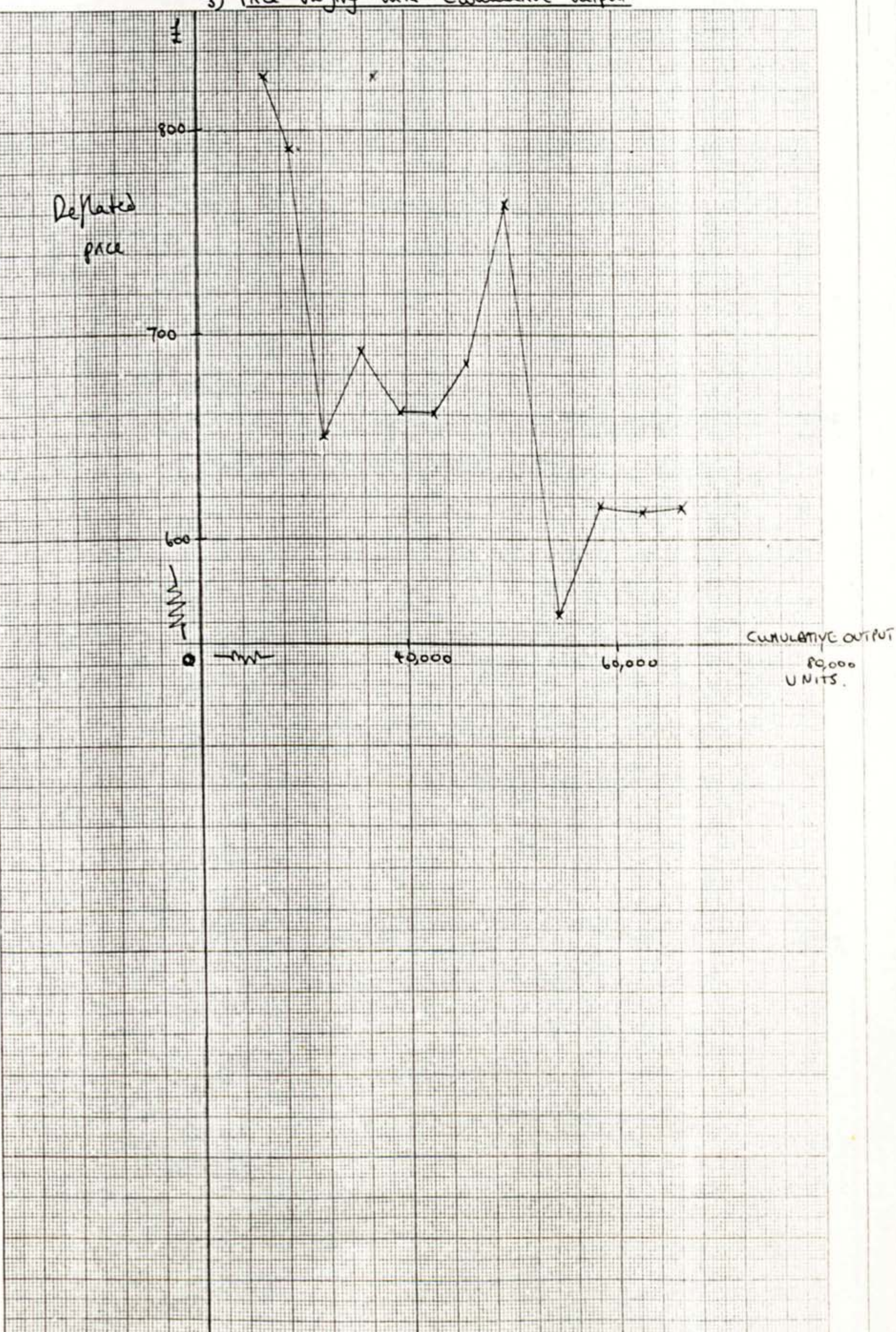


Graph D.2 Variation in average price of a rectifier (BOC AE) with elapsed time, output volume and cumulative output, 1966-77 (BOC AE data)

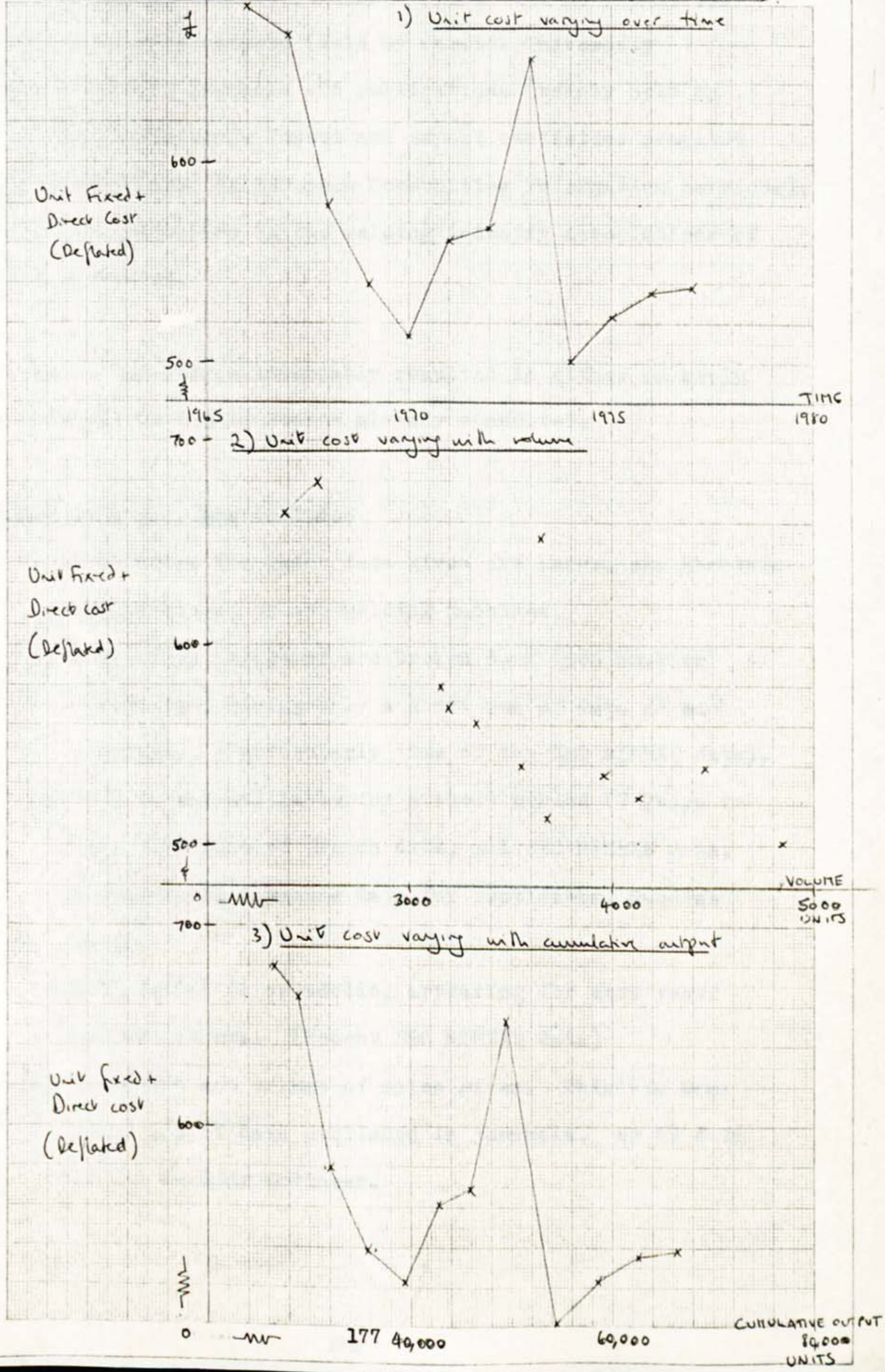


Graph D.3 Variation in average price of a rectifier (BOC AE) with cumulative output

3) Price varying with Cumulative output



Graph D.4 Variation in average cost of a rectifier (BOC AE) with each of elapsed time, output volumes and cumulative output, 1966-77 (BOC AE data)



D.1.2) Data from Arc welding equipment Industries of other countries

Data

Sources consulted include published statistics on industrial production in each country (held by Warwick University Library); welding journals and publications (mainly held by the Welding Institute); Import and Export statistics compiled by EEC NIMEXE (held by European Communities Information Services); and direct application to the welding industry associations of various countries.

NB. The latter source invariably resulted in either no reply or a referral to a data source already consulted.

Problems with the data include;

a) Categories for which data given are large. eg. Electric arc machines, or arc welding machines.

b) Categories change or are broken down into smaller categories, giving only a short run of data in each category. (Particularly time of the EEC NIMEXE data).

c) Data is onlyavailable for a short period (7 years or less) (eg most of French data, all EEC NIMEXE data, German data, Japanese data for rectifiers, Swedish data).

d) Information is spasmodic, appearing for some years but not others. (Recent EEC NIMEXE data)

e) Value but not volume of sales given. This was true for a lot of data published in journals. eg US data in the Welding Engineer.

Deflating Indices Selected from one source book, mostly on a subjective evaluation of the most suitable category in price index series.

Details of the sources and type of data and results of analyses are given under the headings of each country for which data was found.

A summary of results (Table D.6). Data (Tables D.7 to D.19) and graphs (D.5 to D.24) are given at the end of this section. (Page 193)

1.2.1 FRANCE

There were four main sources of data, not all providing data suitable for analysis.

a) Annuaire de Statistique Industrielle, Industries mecanique, electrique et electronique. (Warwick University Library)

   This source provided data on sales value for categories of welding equipment, 1964-1976, but no volumes of sales.

b) Statistique due Commerce Exterieur de la France, Imports and Exports (Warwick University Library)

   Data for rectifiers appears under category 8511.47, rectifiers, and is given for 1972-77. Previous to this, data is given for the wider category of arc welding machines and equipment. (8511.31).

   For data see Table D.7. NB Data for 1975 was missing.

Deflating Index; wholesale prices, semi-manufactured goods.

Results

For both imports and exports, there was very little correlation between average price (deflated) and cumulative output ($r = -0.5$ and -0.002 respectively), with results not significant even at a 90% level of significance. The wide scatter of values for average price (see graphs D.5 to D.7), and the small number of data points both contribute to this result.

For import data, a relationship was suspected between average price and volume of output (see graph D.6), but even though correlation between the two was fairly high ($r = -0.7$), results were not significant at a 95% level, due to the small number of data points.

The volume of output for both exports and imports appeared to be very low, casting doubts on the validity of the data.

Consequently, no further analysis was carried out.

C) EEC NIMEXE data for imports and exports
(European Communities Information Service)
The same categories apply as for source (b), hence data was available for categories;

8511 . 47 Rectifiers, 1972-77

8511 . 31 Arc welding machines and equipment, 1966-71.

Although category 8511 . 47 is more specific, data post 1973 was only included if imports or exports reached a minimal level. Entries were spasmodic and unsuitable for analysis.

Data for category 8511 . 31, imports and exports 1966-71, given in Table D.8, was tested using linear regression analysis.

Deflating Index; Wholesale prices, semi-manufactured goods.

Results

Data for imports given average prices (deflated) which vary little over the period. (See graph D.8) Correlation between deflated price and cumulative output (log/log model), with $r = -0.6$, was not significant at 90% level of significance.

Export data did give a significant correlation between deflated price and cumulative output (log/log model), with $r = -0.776$, significant at a 95% level. (See graph D.9) Multiple regression tests on the data for exports produced the following results (using a linear model).

On cumulative output; $R^2 = 65.1\%$, significant at 95%
On volume of output; $R^2 = 17.8\%$, not significant at 95%
On Elapsed time; $R^2 = 64.6\%$, significant at just less than 95%

The inclusion of a further variable with cumulative output did not significantly improve the fit of the model.

d) Information on the French arc welding equipment industry, supplied by S.N.S. (French company owned by BOC)

Data

Contributors to the statistics included major french manufacturers, (Etarc, Sarazin, SAF, Armco, Commercy, SNS), and importers (Arcos, Messer, Exotherme, ESAB, Oxhydrique, Philips)

Data was taken from sector II.2, arc welding equipment, with two relevant categories.

i) 3012, Rectifiers (mainly TIG and DC Manual)

ii) 3061 (MIG sets with separate wire feed units) and
3062 (" " " wire feeder incorporated).
For data see Tables D.9 and D.10.

Deflating Index; Wholesale prices, semi-manufactured goods.

Results

Data for category 3012, rectifiers, was only available for 1972-75 and 1977, and gave no perceptible trend in average deflated price(See graph D.10). Correlation between average price and cumulative output was very low ($r = 0.002$), and was not significant at a 95% level.

Data for 3061 and 3062, MIG rectifiers, was available for 1968-77 and was combined to give one set of data for MIG sets. However, the average deflated price again showed no trend (See graph D.11), and correlation between average price and cumulative output was again not significant at 95% level ($r = 0.09$).

FRANCE - summary

Although three of the four sources gave useable sets of data on volume and value of sales of either rectifiers or arc welding equipment, only one produced a significant correlation between average price and cumulative output, on a log/log model. (EEC NIMEXE data for exports, 1966-71).

In general, data was unsatisfactory and most sets had few data points. As a result, in most cases average price (deflated) either fluctuated widely or showed no trend over the period.

1.2.2. Germany

There were two main sources of data.

a) Statistiches Bundesamt Wiesbaden Industrie Und Handwerk Reiche 3 Industrielle Produktion W. Kohlhammer Verlag (Warwick University Library)

Data was available for the following:

i) Category 3632, Electric welding machines, 1962-69
ii) " 3632-18, Rectifiers, 1970-77.

For data see Table D.11 and D.12.

Deflating Index; Producer prices, investment goods.

Results

The data for electric welding machines 1962-69 gives an average deflated price which rises steadily until 1967 and then declines slightly. (See graph D.12). Correlation between average price and cumulative output is therefore positive, $r = 0.85$, significant at a 99% level.

Multiple regression analysis produced the followijg results.

Cumulative output; R^2 = 71.6%, significant at 99%
Volume of output; R^2 = 5.4%, not significant at 95%
Elapsed time; R^2 = 69.6%, significant at 97.5%

Inclusion of the variable volume of output with cumulative output significantly improves the fit of the model at a 99.7% level of significance (R^2 = 91.3%).

The lack of correlation between price and volume can be seen from graph D.13.

Data for rectifiers, category 3632-18, 1970-77, again gives a significant correlation between average deflated price and cumulative output on a log/log model (C = 0.88, significant at 99% level).

Multiple regression analysis produced the following results:

Cumulative output: R^2 = 77.4%, significant at 99%
Volume of output : R^2 = 33.8%, not significant at 95%
Elapsed time: R^2 = 83.7%, significant at 99.8%

The inclusion of a further variable with elapsed time did not significantly improve the fit of the model.

However the apparent drop in volume and value of sales over the period 1970-72 (See graph D.14) throws doubt on the validity of this data.

b) EEC NIMEXE data for imports and exports

(European Communities Information Services)

As before data was available for the following:

i) Category 8511.31 arc welding machines 1966-71

ii) " 8511.47 rectifiers 1972-77

Data available for category (ii) was however too spasmodic to be useful.

For data from category (i), See Table D.13.
Deflating Index: Producer prices, investment goods.

Results

Import data for arc welding machines 1966-71 shows little variation in deflated average price over this period (see graph D.15). Correlation between average price and cumulative output was not in fact significant at a 95% level ($r = -0.01$).

Export data shows deflated average price declining then rising (see graph D.16). Again correlation with cumulative output was not significant at 95% level, ($r = -0.27$). Correlation between average price and output volumes was not suspected.

GERMANY - Summary

Data from statistiches Bundesamt (government sources) gave significant relationships between deflated price and each of cumulative output and elapsed time (see (a) above). However, there is some doubt about the validity of the data, as volumes were apparently declining over 1970-72, a period of growth in the industry as a whole.

EEC NIMEXE data produced no significant correlations, and no apparent trends in average price.

1.2.3 UNITED STATES

Results are given for the following data sources:

a) Annual supplement of the Welding Engineer (Journal held by the welding Institute).

Data is given for value of annual sales of arc welding equipment, but not for volumes, so is unsuitable for analysis in this context.

b) US Department of Commerce. Social and Economic Statistics Administration, Bureau of Census 1972, Census of Manufacturers (Warwick University Library)

Data was available for the value of shipments, value added, and cost of materials of shipments of arc welding equipment from the USA, covering the period 1958-72. Cost of materials included actual materials, fuel, and bought-in parts.

The ratio of cost of materials per dollar of shipments was given, and was used in this case as the dependent variable.

Cumulative dollars of shipments, in constant money terms, was used to represent cumulative output for analysis purposes. See Table D.14.

Deflating Index. Wholesale prices of Ondustrial goods.

Results

There was a significant correlation between cost of materials per dollar of shipments and cumulative dollars of shipments, (in constant money terms), at a level of 99.9% ($r = -0.88$), using the log/log model. See graph D.17.

Multiple regression analysis produced the following results:

Cumulative output;	$R^2 = 77.5\%$,	Significant at	99.99%
Volume of output;	$R^2 = 55.6\%$,	" "	99.0%
Elapsed time;	$R^2 = 76.9\%$,	" "	99.99%

Inclusion of further variables with cumulative output did not significantly improve the fit of the model.

1.2.4 JAPAN

There was only one source of data, the Japanese Welding News. Issues for 1973 and earlier are held by the Welding Institute. Since 1973 there has not been an edition issued in English, and so copies are no longer kept by the institute. However, the journal is taken by BOC overseas sales staff, and they supplied relevant tables from more recent issues.

Data was available for the following:

Arc welding machines, volume and value of sales, 1946-70.

DC arc welders, volume and value of sales, 1965-71, 1975 and 76.

For data see Tables D.15 and D.16.

Deflating Index; Wholesale price index 1948-71, producer prices, total manufactured goods, 1967-77.

Results

a) The results for arc welding machines 1946-70 show a deflated price which rose from 1948-55, fell steadily between 1955 and 1965, and then rose again from 1965-70. (See graph D.18)

There was no significant correlation between deflated price and cumulative output, and none suspected between price and volume.

Comparison of movements in average price over differing periods, where volume growth is different, is investigated in D.4.2.

b) Data for DC arc welders, 1965-71, 1975 and 1976 gives a significant correlation between average price (deflated) and cumulative output (log/log mod el), significant at 95% level ($r = -0.74$). (See graph D.19).

Multiple regression analysis gave the following results;

Cumulative output; R^2 = 46.1%, significant at 93.75%

Volume of output; R^2 = 2.13%, not significant at 90%

Elapsed time; R^2 = 43.6%, significant at 93%

The inclusion of a further variable in the model with cumulative output did not significantly improve the fit of the model.

JAPAN Summary

Data for DC Arc welders 1965-76 gives significant results, whereas that for arc welding machines 1948-70 does not. However, the latter will be tested later by breaking the whole period down into those with differing rates of volume growth. (See D.4.2)

1.2.5 SWEDEN

Results are given from testing data from the only source, Produktion av varor ochtjänster för delade enligt CCC - nomenktaturer och enligt SITC - revision 2 (Warwick University Library).

The category finally concluded to be the right one was category 8511 - 301 ' för svetsning eller skarning' (welding and cutting).

The source gives data for sales values 1968-76, but volumes for only 1973-76, giving only a short run of useable data. (See Table D.17)

Deflating Index; Producer prices for manufactured goods (1970 = 100).

There was no significant correlation between deflated average price and cumulative output, and no other correlations were suspected. (See graph D.20).

1.2.6 BELGIUM - LUXEMBOURG

Results are given for the only source of data, EEC NIMEXE data for imports and exports.

Again, the only useable data was for imports and exports of arc welding machines, 1966-71. (For data see Table D.18).

Deflating Index; Wholesale prices, semi - manufactured goods (France), in the absence of an index specifically, for Belgium or Luxembourg.

Results show no significant correlation between price and cumulative output, as is evident from the graphs. (D.21 and D.22)

Export data however does reveal a fairly significant correlation between deflated average price and volume, significant at 97.5% ($r = -0.87$). Although there was no significant correlation between average price and elapsed time, the variable time included in the model with output volume did significantly improve the fit of the model at 95% level.

1.2.7 NETHERLANDS

Results are given for the only source of data, EEC NIMEXE data for imports and exports. Again the only useable data was for volume and value of arc welding machines, 1966-71. (For data see Table D.19)

Deflating Index; Wholesale prices, semi - manufactured goods (France).

Results from inport data give a significant correlation between deflated average price and cumulative output, at a level of significance of 97.5% (= -0.87). See graph D.23.

Multiple regression analysis gave the following results:

Cumulative output;	$R^2 = 77.3\%$,	significant at 97.5%
Output volume;	$R^2 = 79.2\%$,	" " 98%
Elapsed time;	$R^2 = 73.8\%$,	" " 95%

Inclusion of more than one variable in a model with volume of output did not significantly improve the fit of the model.

Export data gave a positive correlation between deflated average price and cumulative output, significance at 99%, $r = +0.9$. See graph D.24.

Multiple regression analysis produced the following results:

Cumulative output;	$R^2 = 79.0\%$,	significant at 97.5%
Volume of output;	$R^2 = 9.42\%$,	not significant at 95.0%
Elapsed time;	$R^2 = 82.6\%$,	significant at 98.07%

The inclusion of cumulative output in the model with elapsed time significantly improved the fit of the model, at a 95% level of significance.

1.2.8 <u>Summary</u> (See Table D.6)

Data from arc welding equipment industries of other countries, even when useable, frequently gave no perceptible trend in deflated average price, and no significant correlation between average price and cumulative output. There was usually some reason for this, either the short run of available data, wide categories of equipment covered by the data, or data being for exports and imports and not necessarily consistent over periods of time.

For this reason, sets of data which gave no significant correlations, and had at least one of the above defects, were omitted from the subsequent analyses. This reduced the number of sets of data used from 18 to 8. However, even these sets frequently had defects, or doubtful validity, and this should be borne in mind when interpreting the results.

Table D.6. Summary of results from analyses of data from arc welding equipment industries of other countries (See D.1.2 for details).

No.	Country	Data: Source	Data: Type	Volume Growth Rate	Test of exp. curve model	Test of other variables	Problems with data	Incl. in final analysis
1	France	Statistique du Commerce Exterieur	Rectifiers, Exports, 1972-77	12.5% p.a.	C = -0.002 not sig. at 5%	Volume not sig. at 5%	Few data points	No
2	France	"	Rectifiers, Imports, 1972-77	29.6% p.a.	C = -0.46 not sig. at 5%	-	"	No
3	France	EEC Nimexe	Welding machines and equipment 1966-71 Exports	1.4% p.a.	C = -0.78 sig. at 5% Slope = 78.0%	Time sig. at 5%. Volume not sig.	Wide category	Yes
4	France	"	" Imports	34.5% p.a.	C = -0.6 not sig. at 5%	-	Wide category	No
5	France	SNS	TIG & DC Rectifiers 1972-77	3.6% p.a.	C = +0.002 not sig. at 5%	-	Inadequate data	No
6	France	"	MIG sets 1968-77	5.5% p.a.	C = +0.09 not sig. at 5%	-	Little variation in price	No

Table D.6. Continued Summary of results from analyses of data from arc welding equipment industries of other countries (See D.1.2 for details).

No.	Country	Data		Volume Growth Rate	Test of exp. curve model	Test of other variables	Problems with data	Incl. in final analysis
		Source	Type					
7	Germany	Statistiches Bundesamt	Electric Welding Machines 1962–69	1.5% p.a.	C = +0.85 sig. at 1% (Slope = 137.5%)	Time sig. at 2.5%. Volume not sig. at 5%	Wide Category	Yes
8	Germany	" Wiesbaden	Rectifiers, 1970–77	Negative	C = –0.89 sig. at 1%, Slope = 24.5%	Time sig. at 0.1%, Volume not sig. at 5%	Declining volumes of sales	Yes
9	"	EEC Nimexe	Arc Welding Machines, Imports 1966–71	9.1% p.a.	C = –0.01 not sig. at 5%	–	Wide Category, few data points	No
10	"	"	Arc Welding Machines, Exports, 1966–71	20.5% p.a.	C = –0.27, not sig. at 5%	–	"	No
11	U.S.A.	US Bureau of Census 1972	Arc Welding equipment, value added + value of shipments 1958–72	4.7% p.a.	C = –0.88, sig. at 0.1%, Slope = 89.2%	Time sig. at 0.1%, Volume sig. at 1%	Dubious (no volumes)	No

Table D.6. Continued — Summary of results from analyses of data from arc welding equipment industries of other countries (See D.1.2 for details).

No.	Country	Data: Source	Data: Type	Volume Growth Rate	Test of exp. curve model	Test of other variables	Problems with data	Incl. in final analysis
12	Japan	Japanese Welding News	Arc Welders 1946–70	39.1% p.a.	Not sig. at 5%	–		Yes
13	"	"	DC Arc Welding M/Cs 1965–71		C = –0.74 sig. at 5%. Slope = 73.7%	Volume sig. at 7%, Time not sig. at 5%		Yes
14	Sweden	Produktion av varor ochjunster	Welding & cutting eqpt. 1973–76	10.6% p.a.	Not sig. at 5%	–	Wide Category, few data points	No
15	Netherlands	EEC Nimexe	Arc Welding m/cs, Imports, 1966–71	13.1% p.a.	C = –0.87 sig. at 2.5% Slope = 71.6%	Time sig. at 5%, Volume sig. at 2%		Yes
16	"	"	Arc Welding m/cs, Exports 1966–71	2.0% p.a.	C = +0.90 sig. at 1% Slope = 161.5%	Time sig. at 1%, Volume not sig. at 5%		Yes
17	Belgium – Luxembourg	"	Arc Welding m/cs, Imports	Negative	C = –0.01 not sig. at 5%	–	Few data points	No
18	"	"	Arc Welding M/cs Exports	Negative	C = 0.08 not sig. at 5%	Volume sig. at 2.5%	"	Yes

Table D.7 France; data for imports and exports, Statistique due Commerce Exterieur de la France

Category 8511 - Rectifiers

Year	Value (M F)	Volume (units)	Deflated Val.(MF)	Deflating Index	Deflated Price(MF)	Cumulative output
Imports						
1972	454	24	414.2	109.6	17.26	104
1973	669	43	549.7	121.7	12.78	147
1974	627	24	403.7	155.3	16.81	171
1975	missing	est 57	missing	153.6		228
1976	1730	87	1067.2	162.2	12.26	315
1977	1893	73	1113.5	170.0	15.25	388
Exports						
1972	621	38	566.6	109.6	14.91	305
1973	731	37	601	121.7	16.23	342
1974	241	10	155	155.3	15.52	352
1975	missing	est-40				392
1976	1229	48	757.7	162.2	15.79	440
1977	1429	56	840.6	170.0	15.01	496

Table D.13 Germany EEC NIMEXE data for imports and exports

Category 8511.31 arc welding machines

Year	Value Special Units	Volume 1000kg	Deflating Index	Defl. Value	Defl. Price	Cumulative Output
Imports						
1966	1006	264	90.7	1109	4.201	2230
1967	1521	390	89.8	1694	4.343	2620
1968	1907	553	89.8	2124	3.840	3173
1969	1485	400	92.7	1602	4.005	3573
1970	2388	558	100	2388	4.280	4131
1971	2053	456	106.2	1933	4.239	4587
Exports						
1966	762	240	90.7	840	3.501	1305
1967	591	214	89.8	658	3.075	1519
1968	642	251	89.8	715	2.848	1770
1969	1111	485	92.7	1198	2.471	2255
1970	1478	505	100	1478	2.927	2760
1971	1581	456	106.2	1489	3.265	3216

Table D.14 USA : Data for industry shipment of arc welding equipment

Deflating Index; Wholesale prices of Industrial goods 1975 = 100

Data

Year	Value of Industry Shipments Million $	Deflating Index	Deflated Value of Industry Shipments Million $	Cost of * Materials per dollar of Shipments	Cum. Output in $ (constant) M $
1958	247.7	54.6	453.7	.55	5685
1959	297.4	55.6	534.9	.55	6220
1960	304.2	55.6	547.1	.54	6767
1961	294.4	55.3	532.4	.55	7800
1962	308.6	55.3	555.0	.56	7855
1963	330.2	55.2	598.2	.51	8453
1964	389.4	55.5	701.6	.52	9154
1965	446.5	56.2	794.5	.53	9949
1966	533.8	57.5	928.3	.53	10877
1967	493.3	58.3	846.1	.48	11723
1968	486.4	59.8	813.4	.47	12537
1969	526.1	61.8	851.3	.48	13388
1970	509.8	64.1	795.3	.49	14183
1971	503.6	66.5	757.3	.48	14941
1972	659.6	68.7	960.1	.48	15901

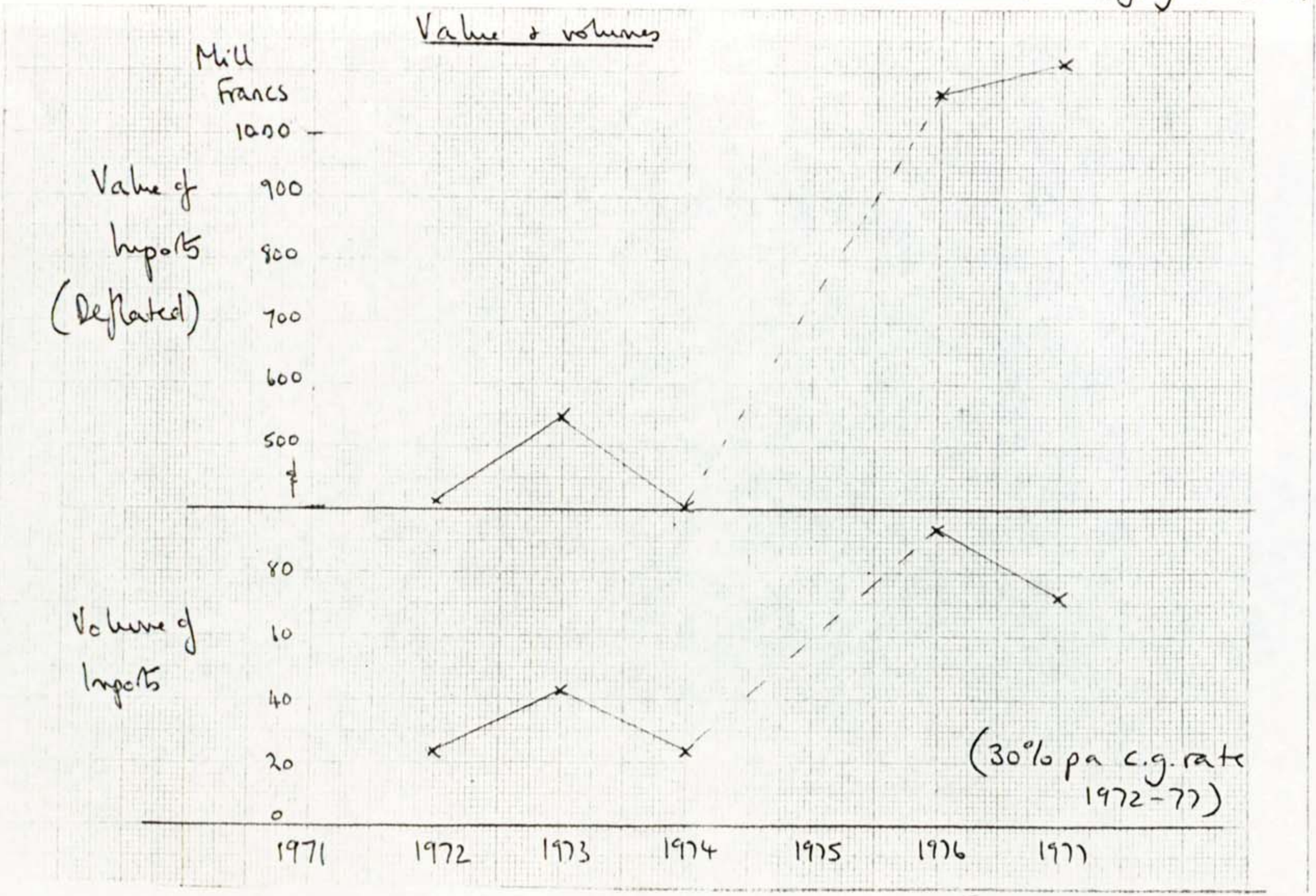
* The dependent variable, cost of materials per dollar of shipments actually represents manufacturing cost per dollar of shipments; since materials includes the cost of materials, supplies, semi-finished goods etc, fuels, electric energy actually consumed or put into production during the year, plus cost of products purchased for resale.

Table D.19 Netherlands : data for imports and exports, EEC NIMEXE

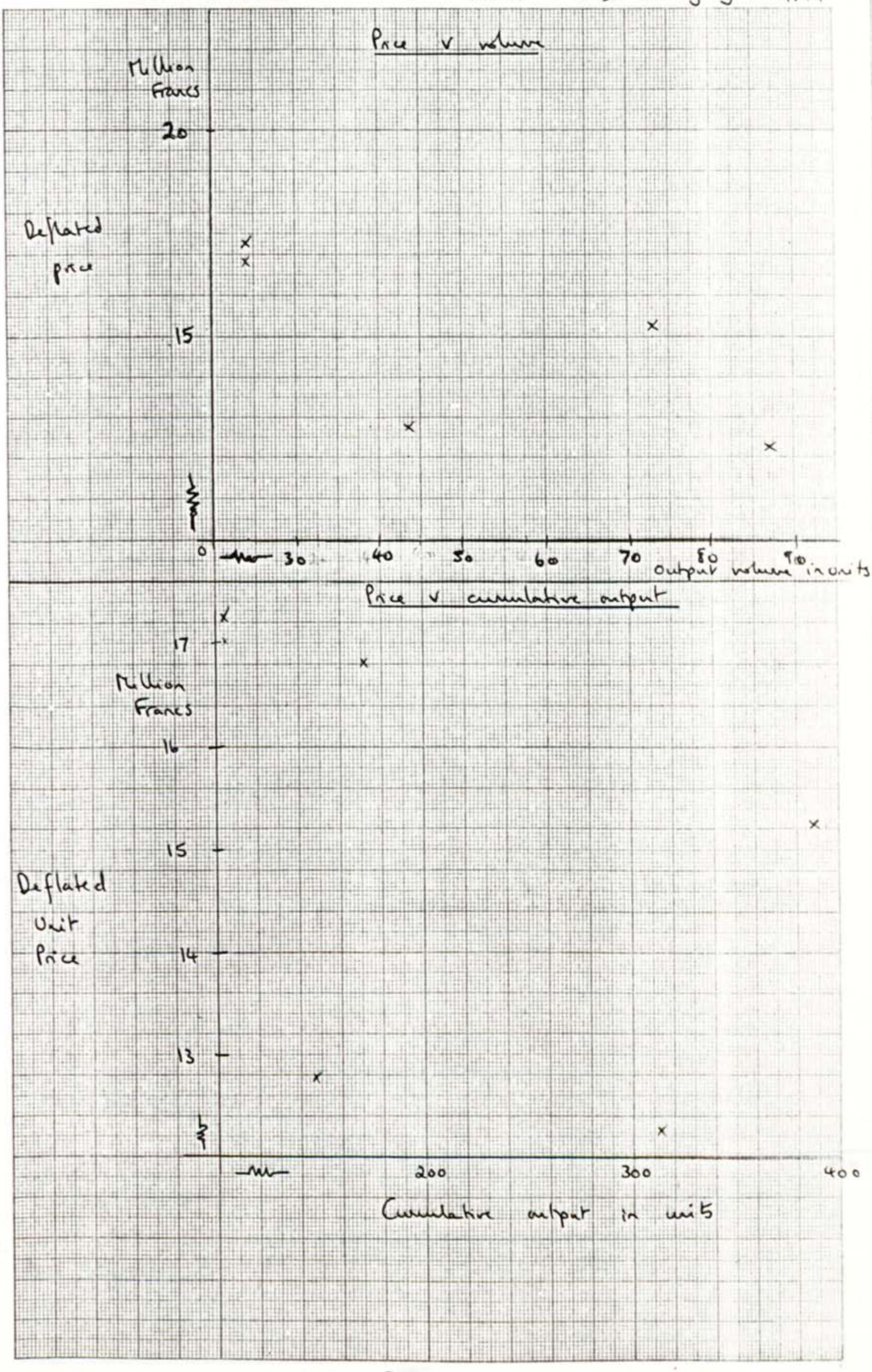
Category 8511.31 Arc Welding Machine

Year	Value (Spec. Units)	Volume 1000kg	Deflating Index	Defl. Value	Defl. Price	Cum Output
Imports						
1966	487	118	87.1	559.1	4.738	1028
1967	882	241	86.9	1014.9	4.211	1269
1968	663	160	85.7	773.6	4.835	1429
1969	806	217	93.7	860.2	3.964	1646
1970	862	246	100	862	3.504	1892
1971	942	268	104	905.77	3.380	2160
Exports						
1966	1082	493	87.1	1242	2.520	6072
1967	1062	448	86.9	1222	2.728	6520
1968	1069	433	85.7	1247	2.881	6953
1969	1371	455	93.7	1463	3.216	7408
1970	1716	550	100	1716	3.120	7958
1971	1726	526	104	1660	3.155	8484

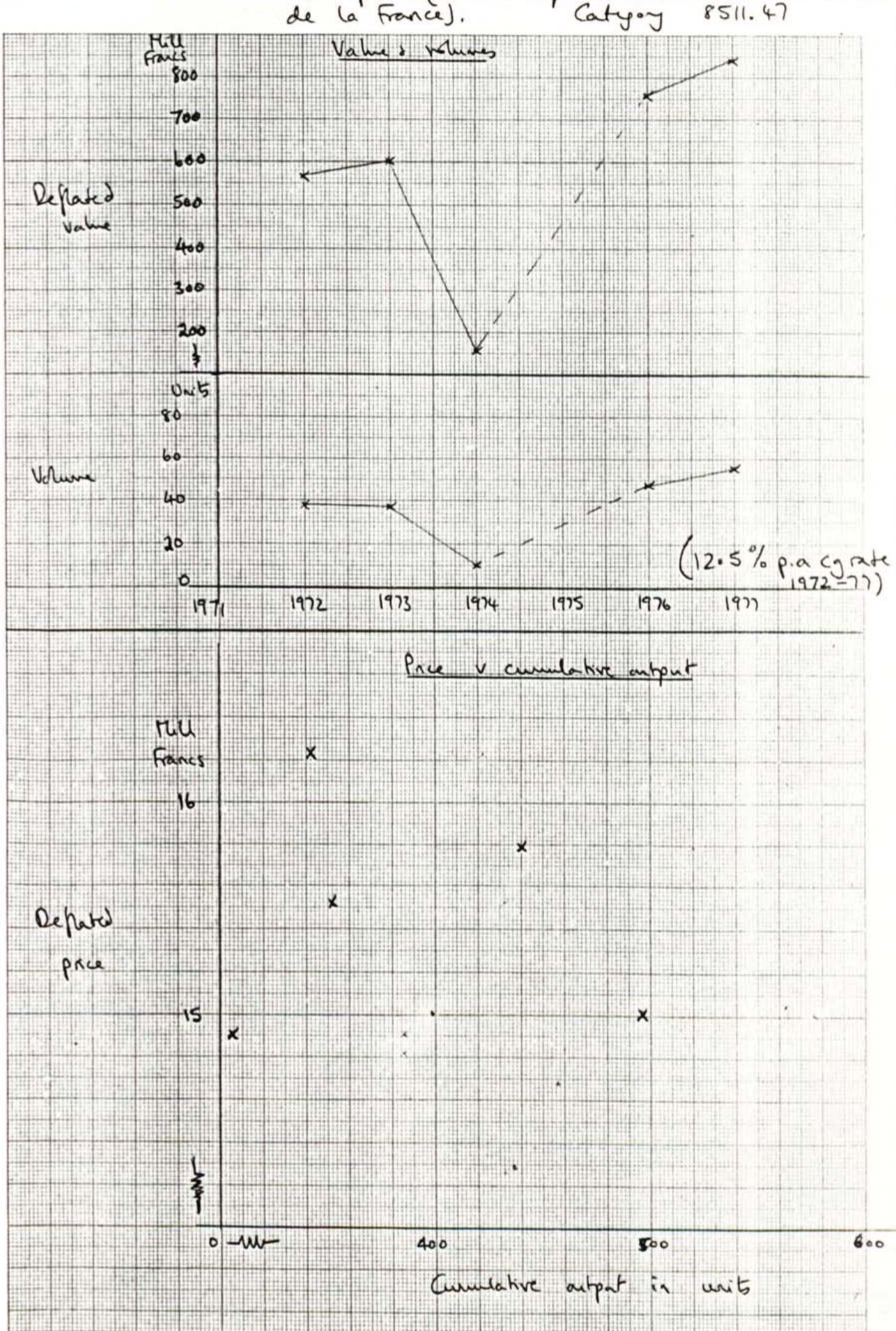
Graph D.5 FRANCE - Data on imports (Statistique du Commerce Exterieur de la France) Category 8511.47



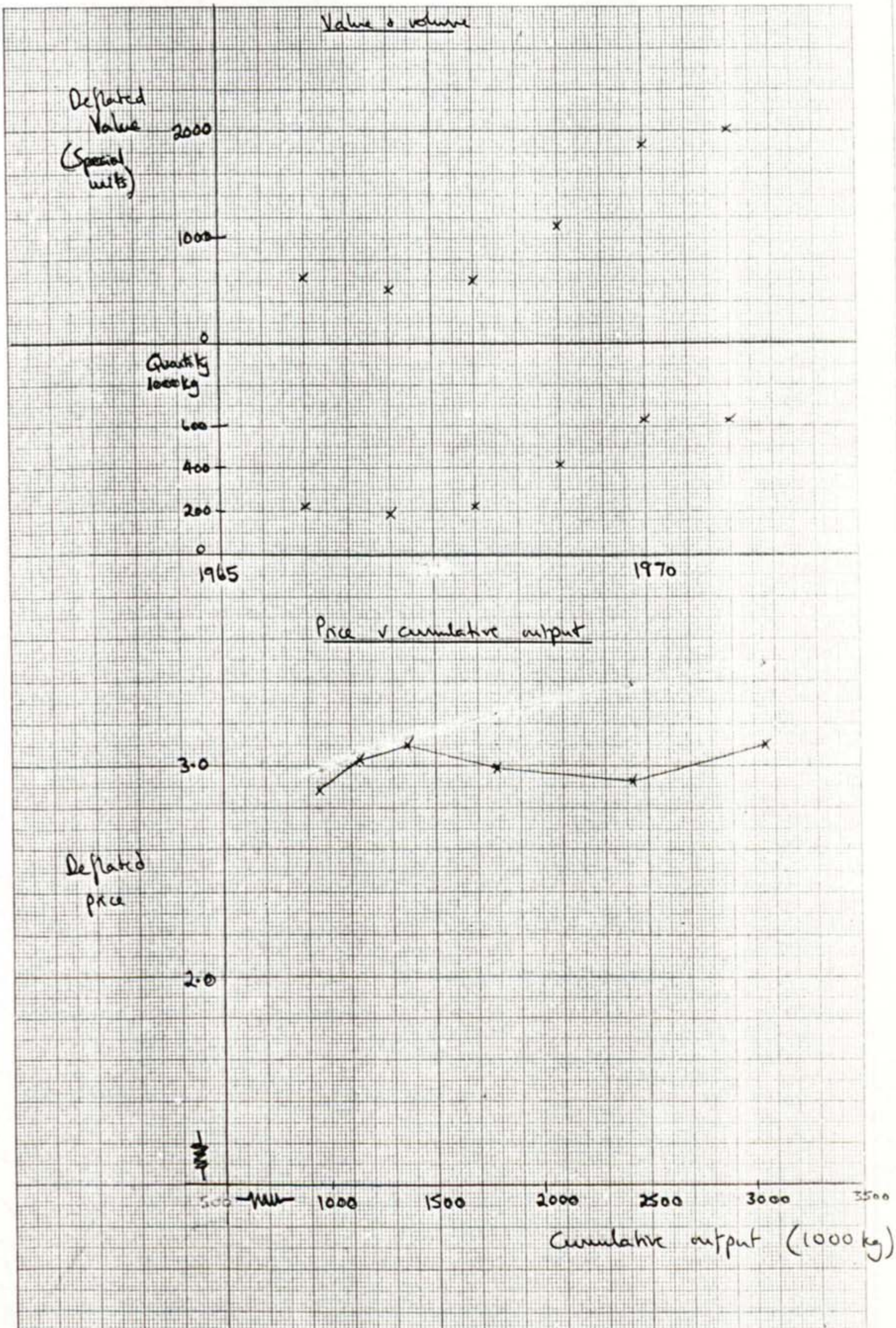
Graph D.6 FRANCE - data on imports (Statistique du Commerce Exterieur de la France). Category 8511.47



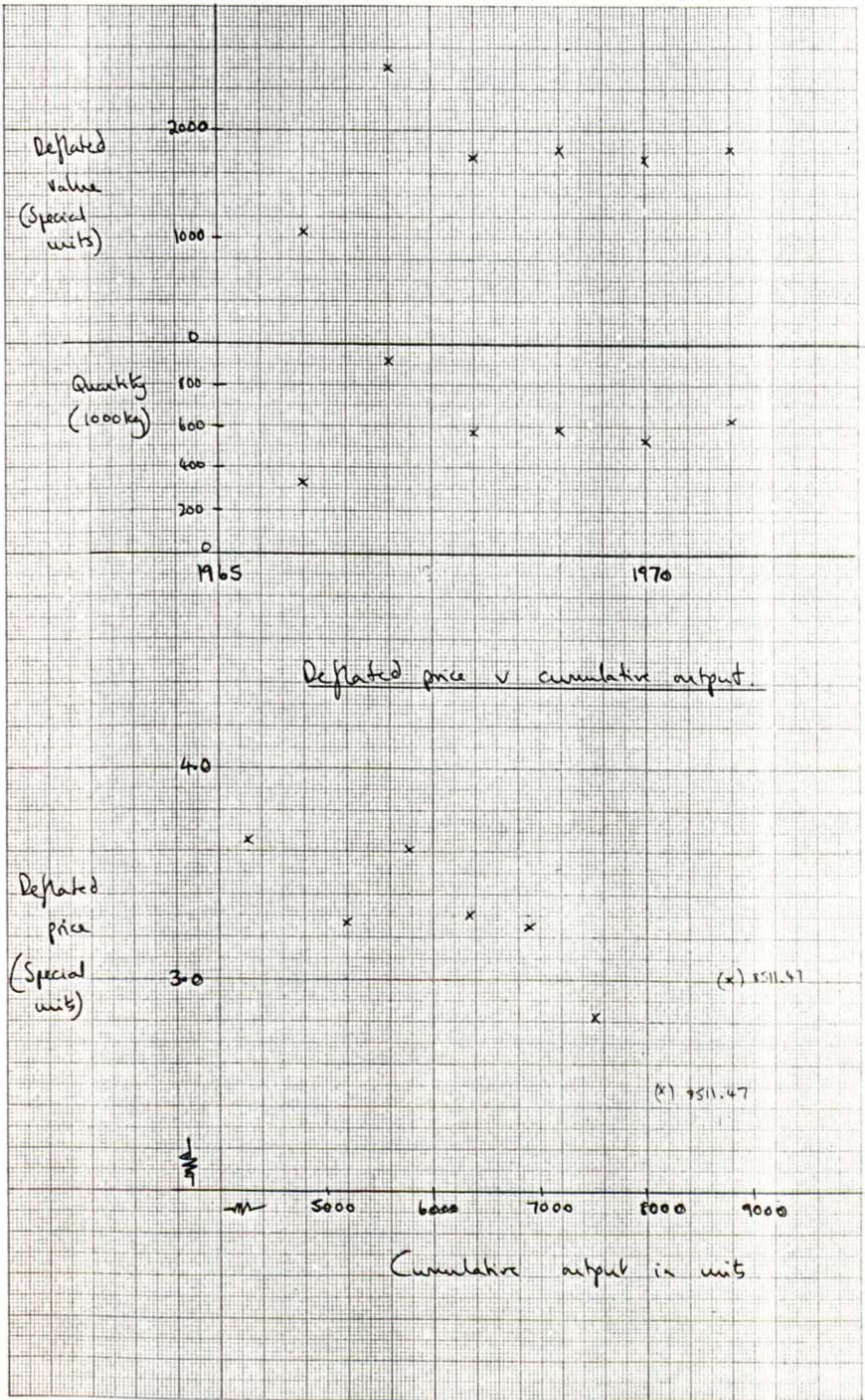
Graph D.7 FRANCE – data on Exports (Statistique du Commerce Exterieur de la France). Category 8511.47



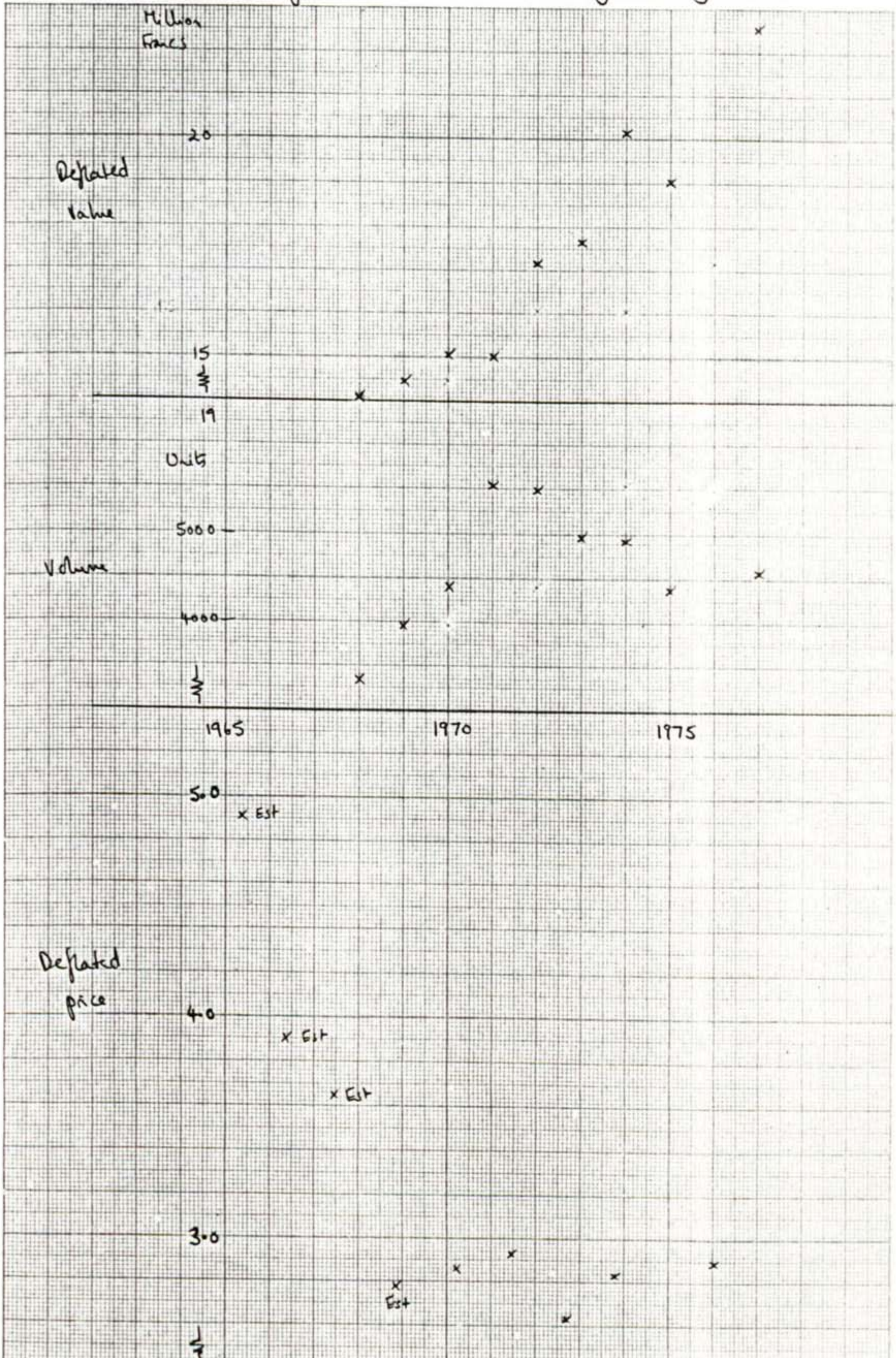
Graph D.8 FRANCE - data on imports (EEC Nimexe). Category 8511.31



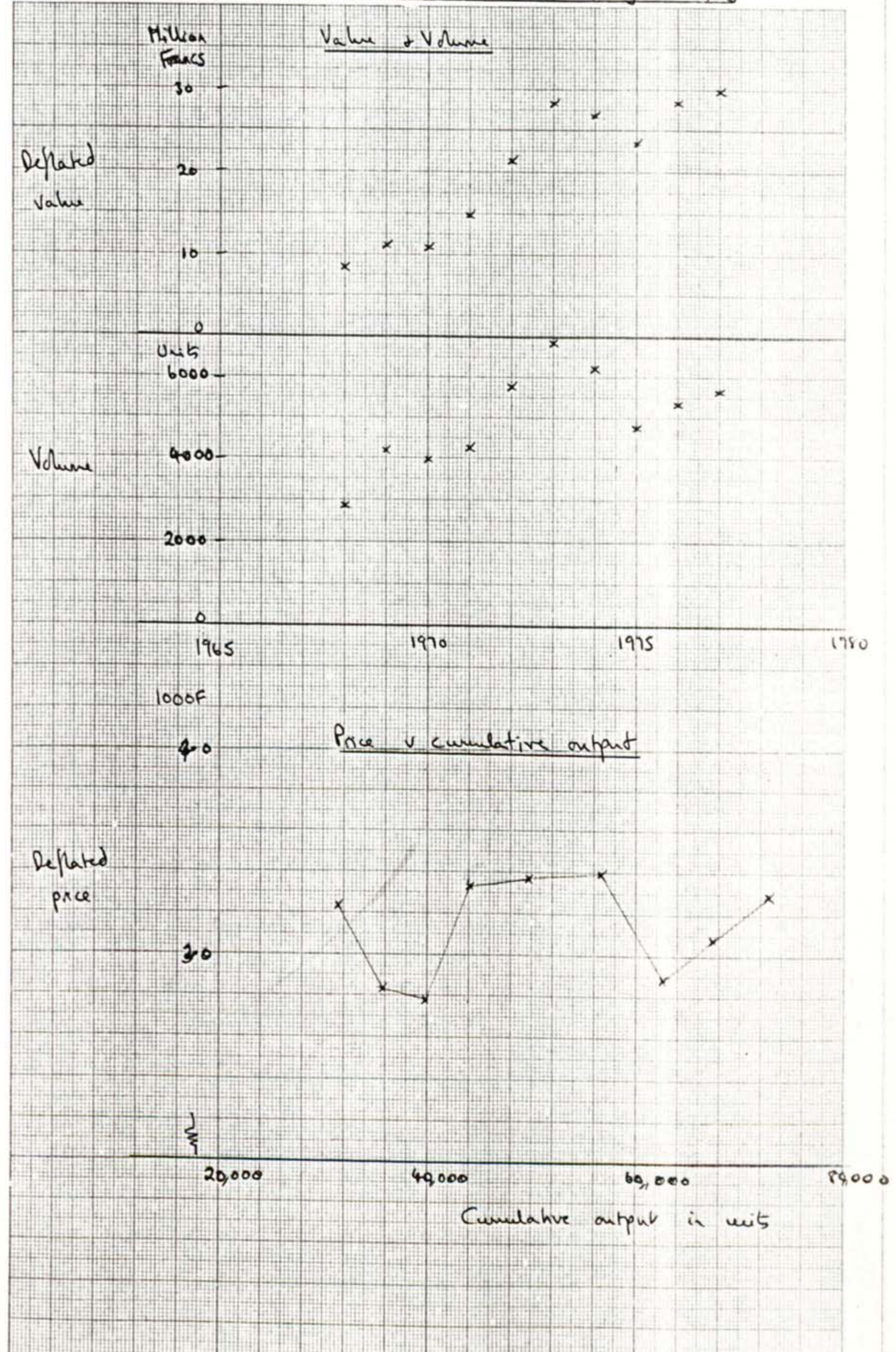
Graph D.9 FRANCE - data on exports (EEC Nimexe) Category 8511.31



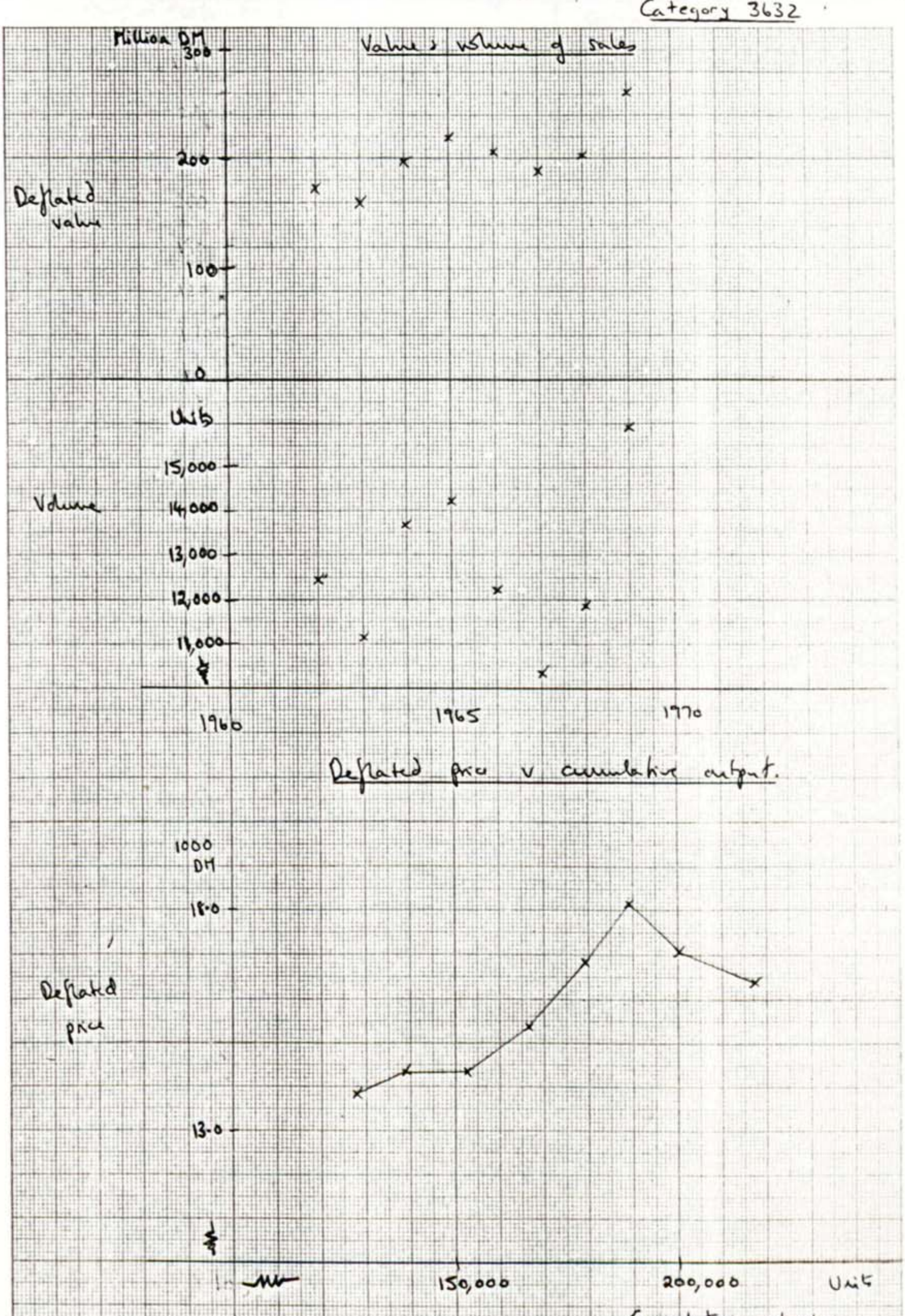
Graph D.10 France - data on Rectifiers (TIG + D.C Manual). Category 3012 of data on French welding industry.



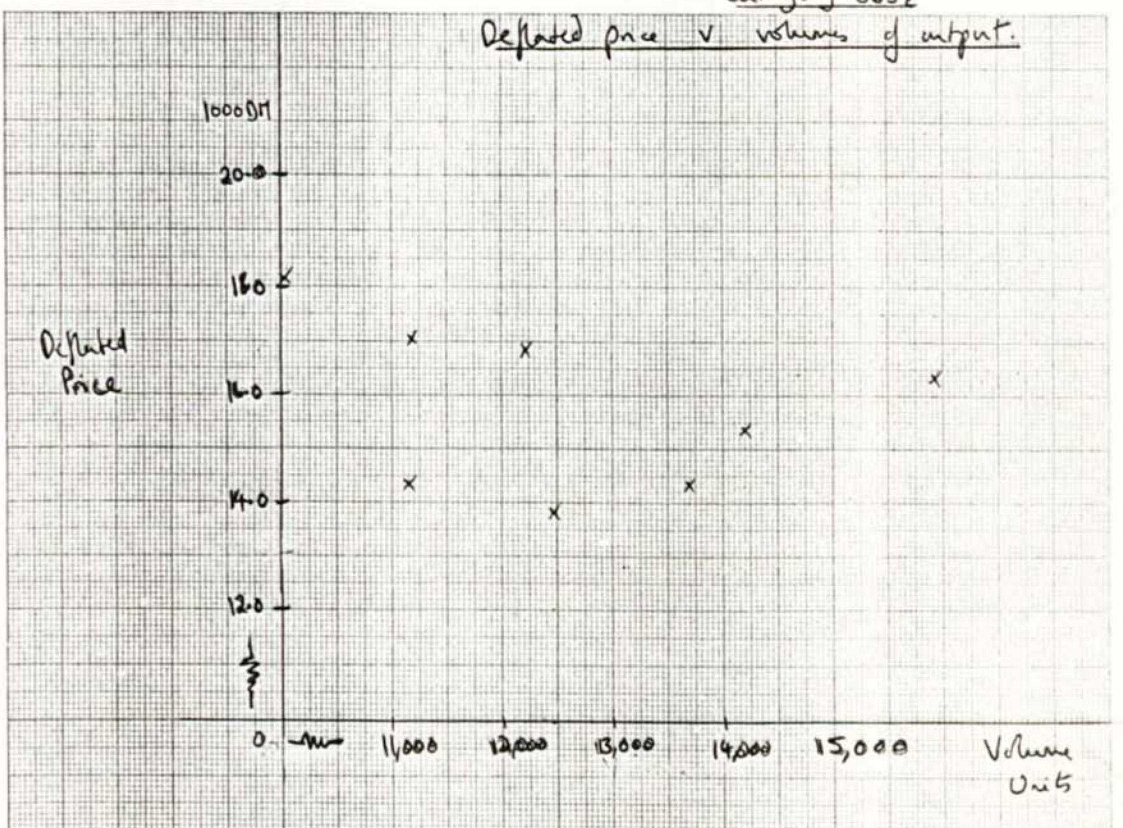
Graph D.11 FRANCE - data on Rectifiers (MIG). Categories 3061 and 3062 of data on the French Welding Industry



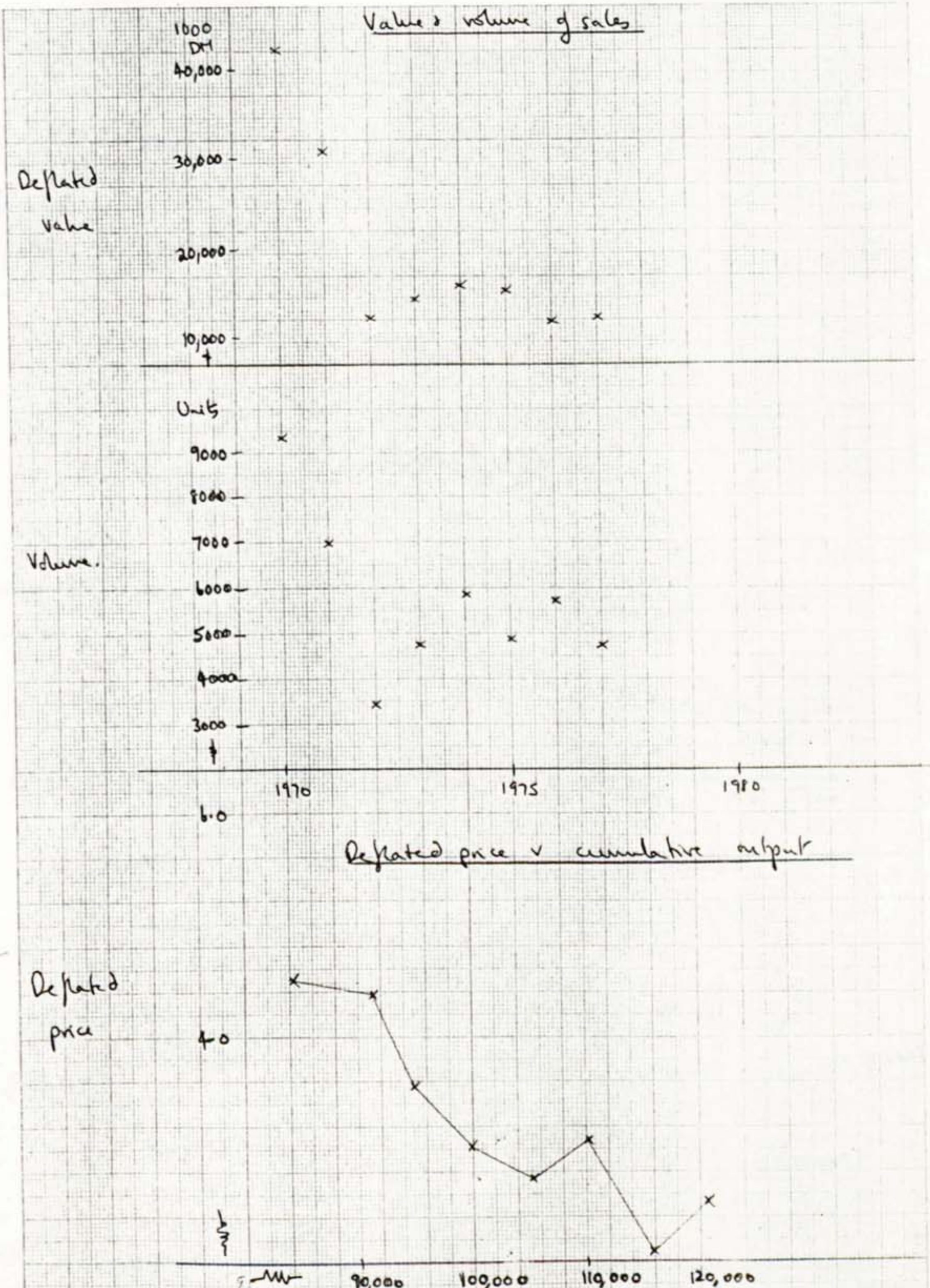
Graph D.12 GERMANY - data on electric welding machines (Government Statistics)
Category 3632



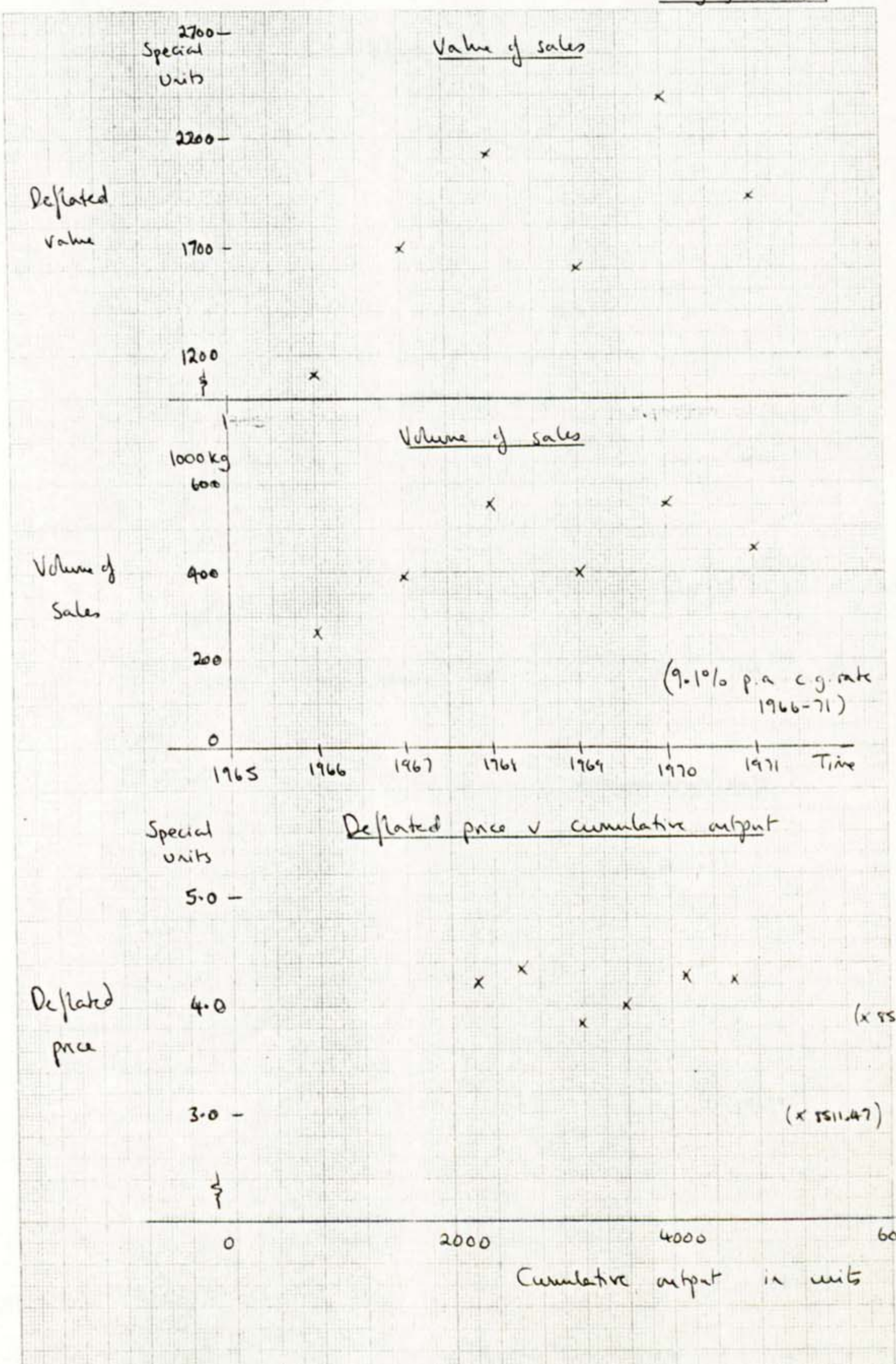
Graph D.13 GERMANY – data on electric welding machines (Government Statistics)
Category 3632



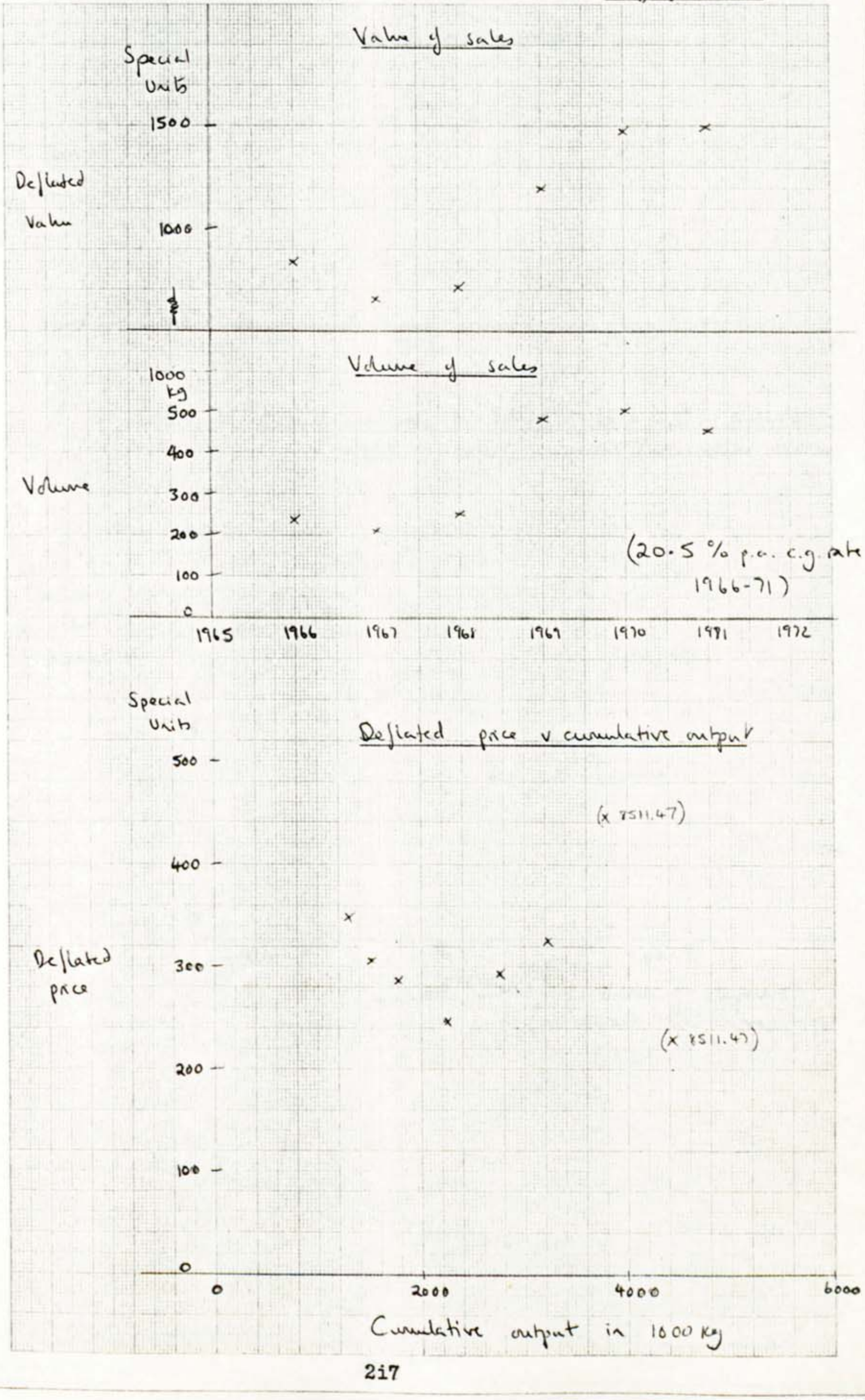
Graph D.14 GERMANY – data on Rectifiers (Government statistics) Category 3632-18



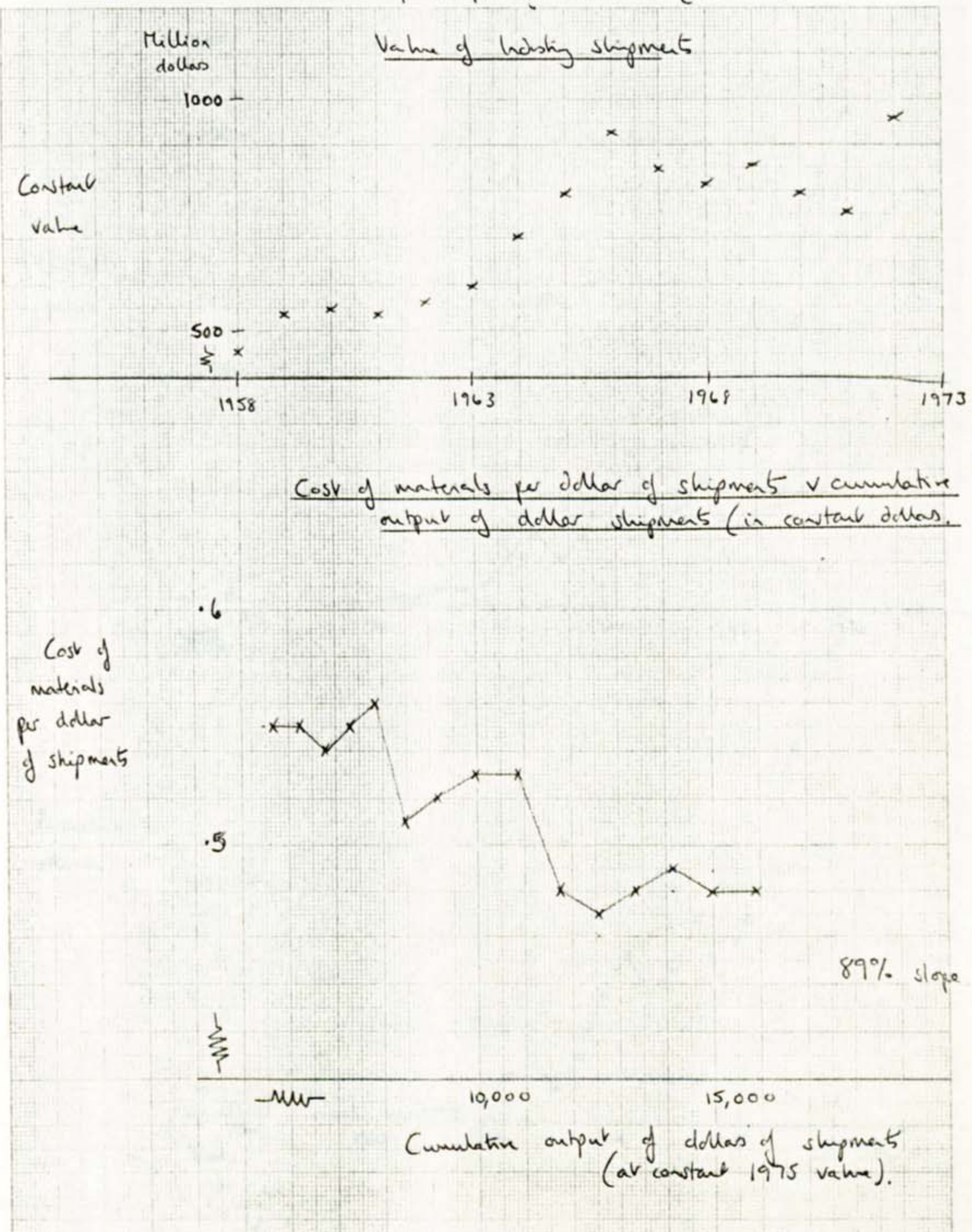
Graph D.15 GERMANY – data on imports of arc welding machines (EEC NIMEXE)
Category 85.11.31



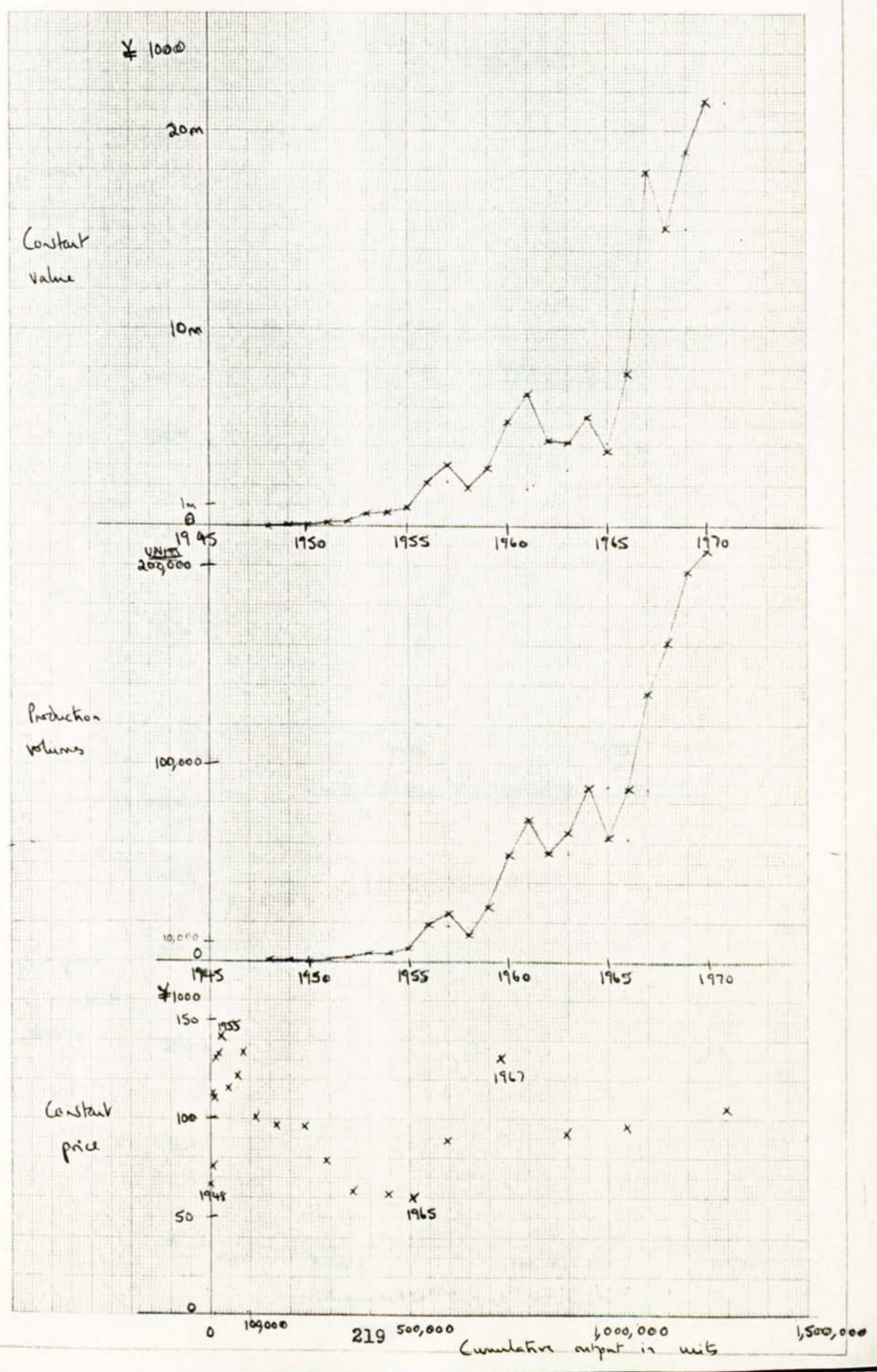
Graph D.16 GERMANY – data on exports of arc welding machines (EEC NIMEXE) Category 8511.31



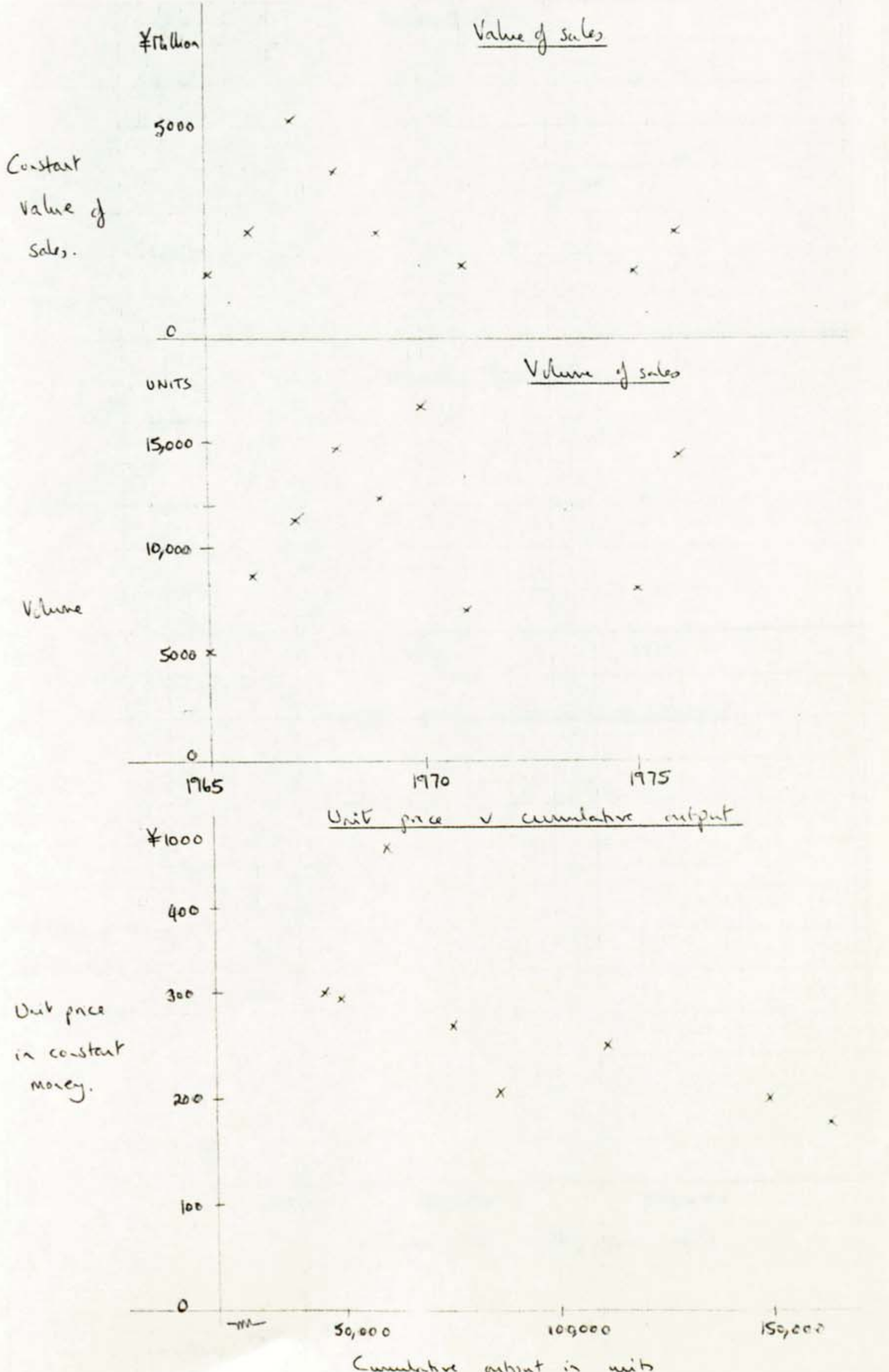
Graph D.17 USA – data on value of industry shipments and cost of materials per dollar of shipments, 1958-72 (Bureau of Census 1972).



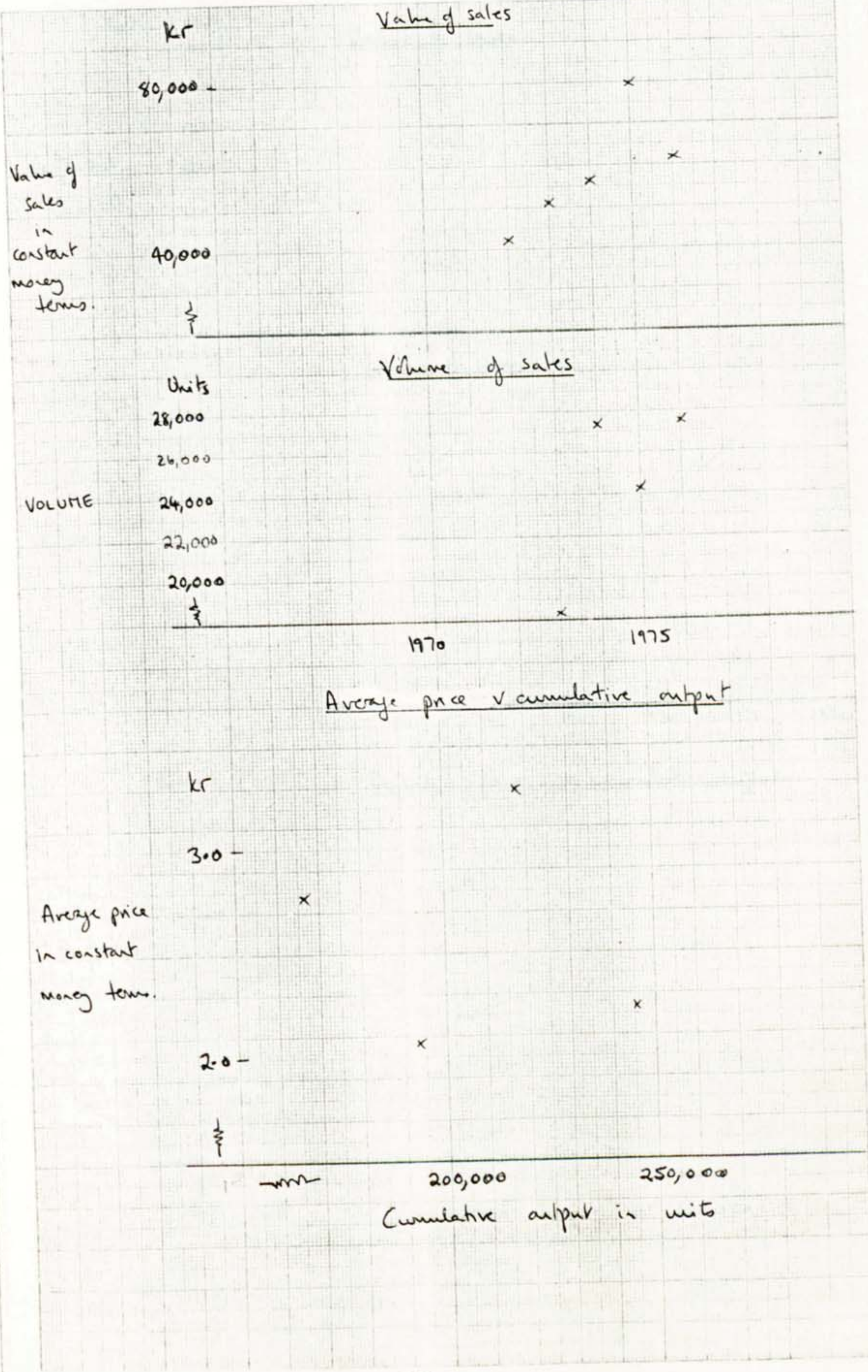
Graph D.18 JAPAN - Data on volume and value of arc welding machines 1946-70



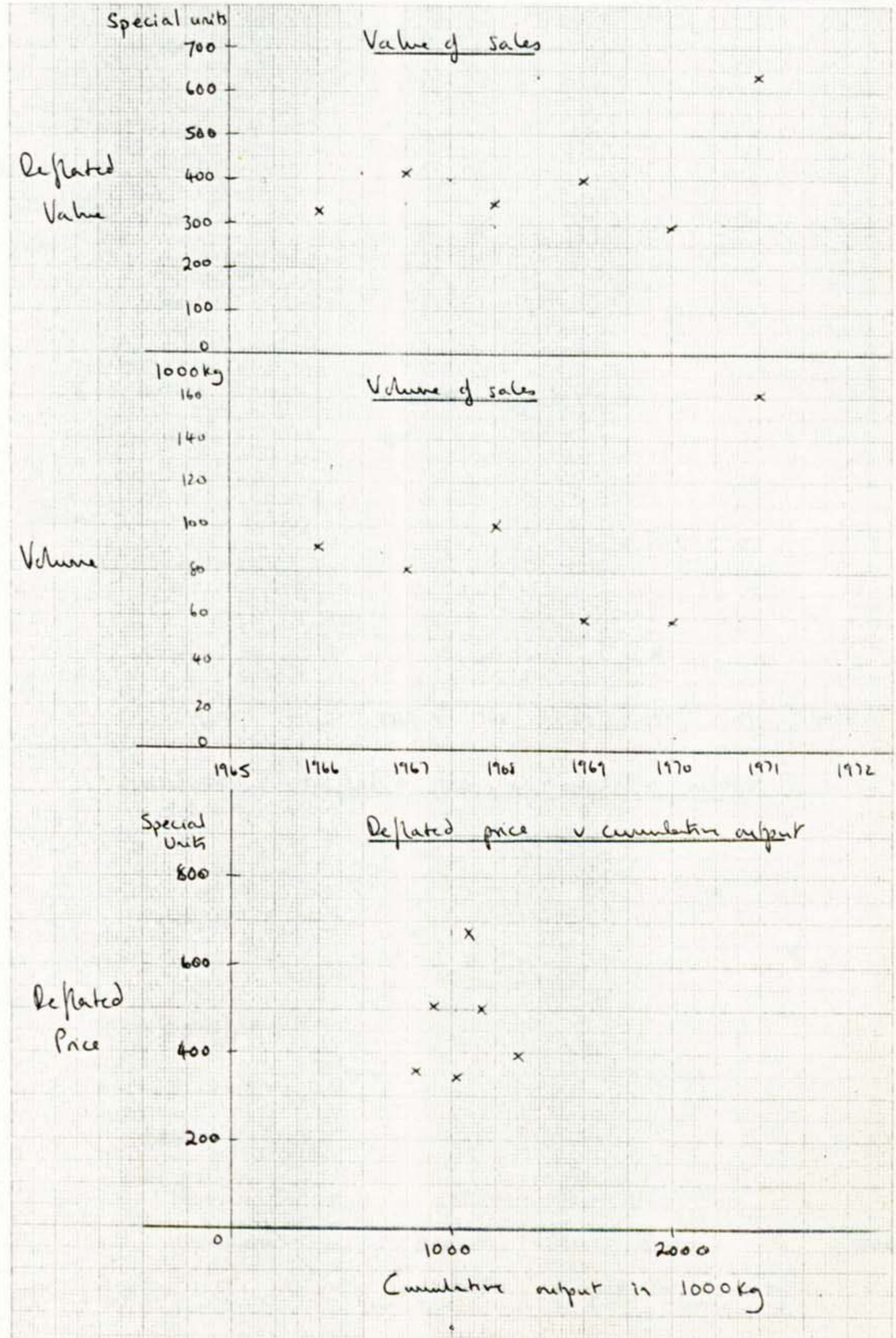
Graph D.19 JAPAN - Data on volume and value of DC arc welding machines 1965-76



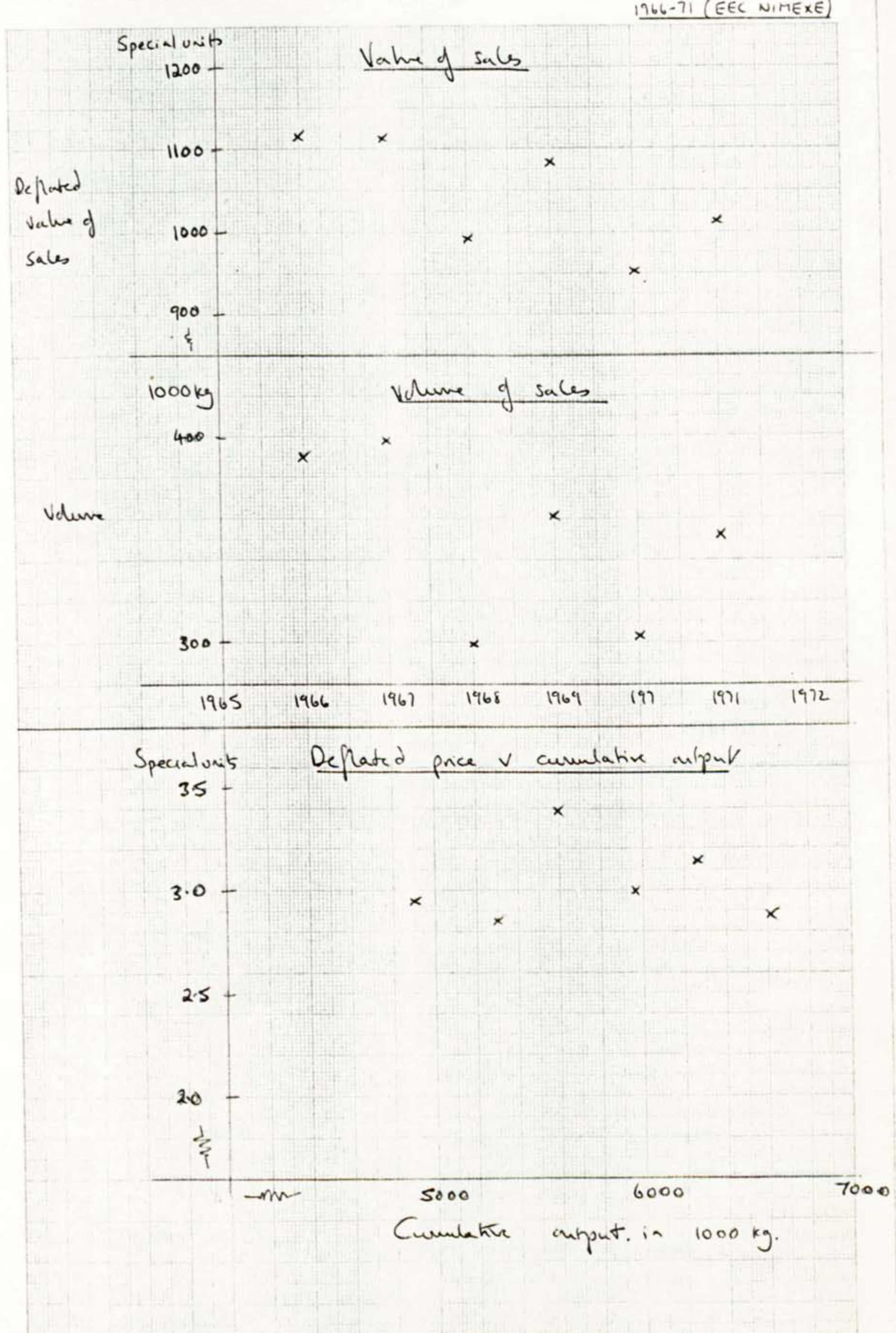
Graph D.20 SWEDEN – Data on volume and value of sales of welding and cutting machines, 1973-76



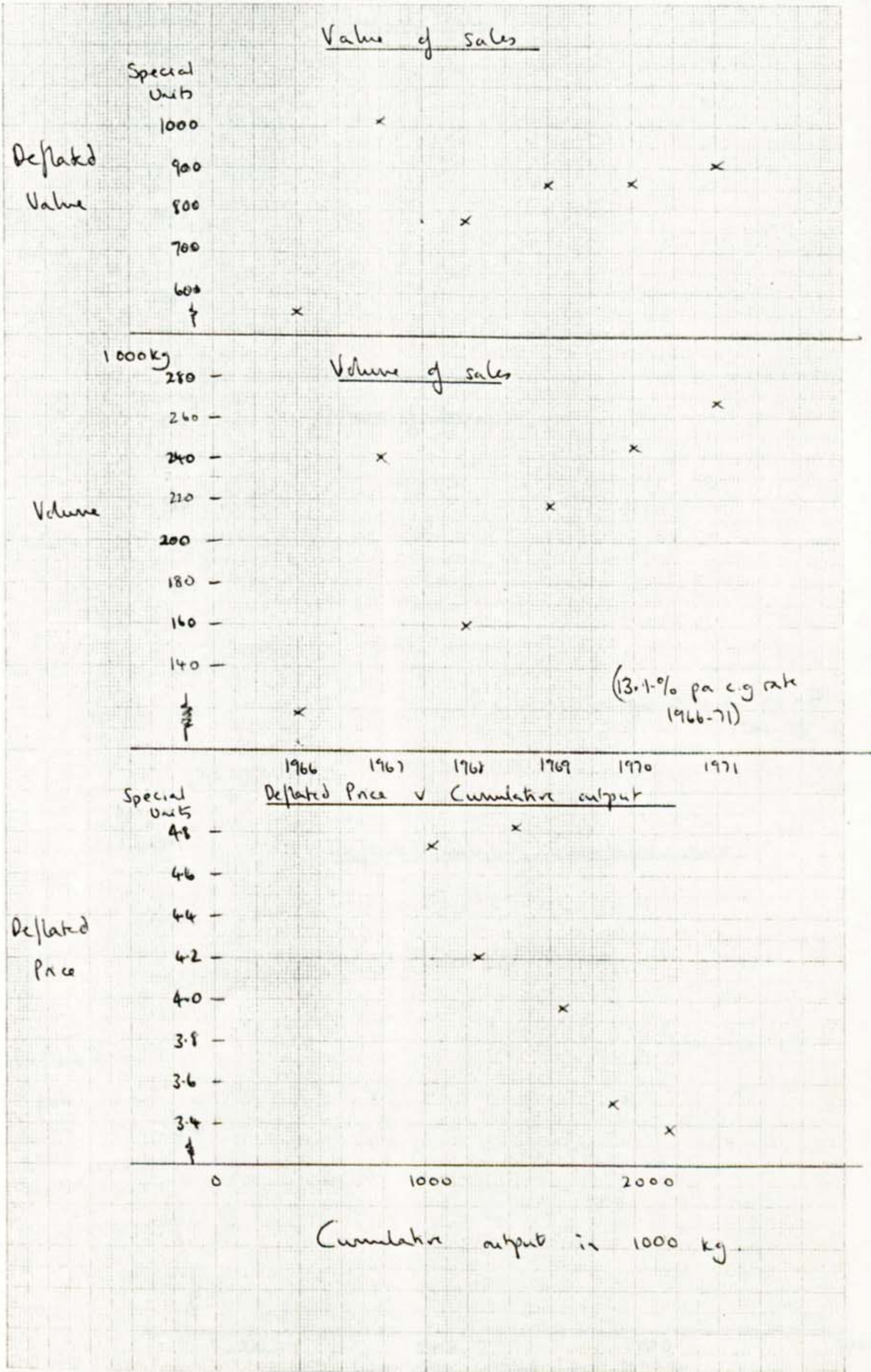
Graph D.21 BELGIUM-LUXEMBOURG Data on arc welding machines, imports, 1966-71 (EEC NIMEXE)



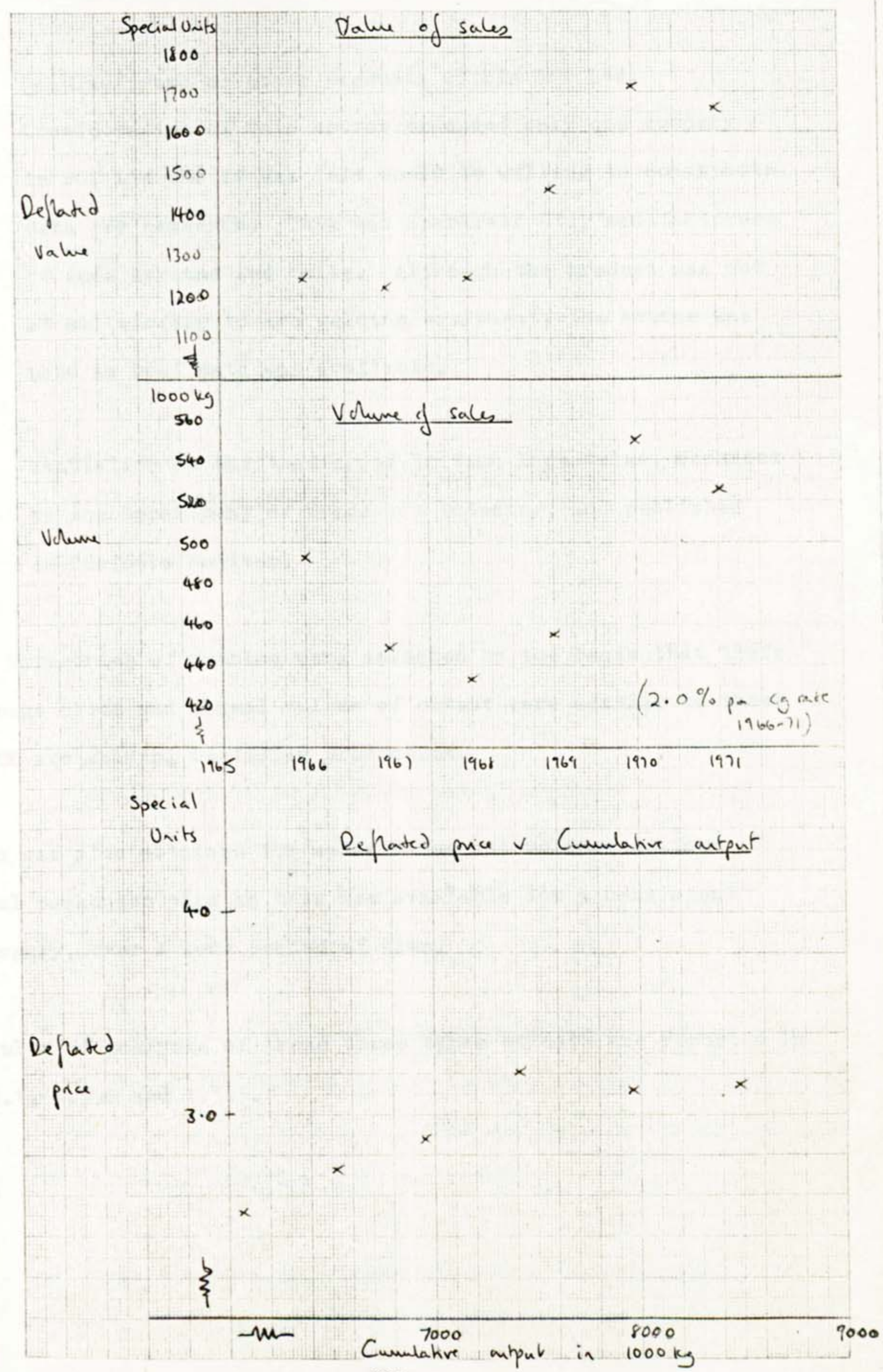
Graph D.22 BELGIUM-LUXEMBOURG Data on arc welding machines, exports 1966-71 (EEC NIMEXE)



Graph D.23 NETHERLANDS - Data on imports of arc welding machines, 1966-71 (EEC NIMEXE)



Graph 0.24 NETHERLANDS Data on exports of arc welding machines, 1966-71 (EEC NIMEXE)



D.1.3 Data from industries manufacturing products other than arc welding equipment

Data sources consisted of the following:

a) Manufacturers of other products within BOC Ltd. Consideration of this source produced only one company in BOC Ltd who it was felt would be willing to contribute data for research. This was Sparklets Ltd, manufacturers of soda syphons and bulbs. Although the product was not at all similar to arc welding equipment, the source was used as cost data was available.

b) Statistics on the trading of British Industries, recorded by the Department of Trade and Industry, and published in Business Monitor.

Six categories of machine were selected on the basis that their average price and annual volume of output were similar to those of UK arc welding rectifier production.

Data was also obtained for sales value and volumes of four wheel passenger cars as this was available for a consistent category, over a long period of time.

Results of analysis of these three types of data are reported in 1.3.1, 1.3.2 and 1.3.3.

1.3.1 Data for sales and cost of production of soda syphons and bulbs

Data

Sales value, volumes, and total costs of manufacture of syphons and bulbs were available for 1956-77, and data for direct and fixed costs separately, from 1968-77. Direct cost included cost of materials, labour, and variable factory overheads. Fixed costs were apportioned to products on the basis of their proportion of sales.

Deflating Index: Index of prices of manufactured goods (Home Sales).

For data see Tables D.20-D.23.

Results

See graphs D.25 and Tables D.24 and D.25

a) Syphons

For all sets of data, there was a significant relationship between the dependent variable and cumulative output, on a log/log model, at a level of significance of at least 99.9% (See Table D.24)

In all cases where the multiple regression test was carried out, the variable representing elapsed time was also significant, but volume of output was not significant at 95% level in two-thirds of the cases.

In general, the linear model tested in the multiple regression tests produced slightly higher values of R^2.

In one case, that of total unit cost 1956-77, inclusion of a further variable significantly improved the fit of the model.

b) <u>Bulbs</u>

A significant relationship between the dependent variable and cumulative output, using a log/log model, was found for all sets of data except that for unit price and cost 1968-77. (See Table D.25). It is evident from the graph (D.28) that little variation in either price or cost per unit occured over this period, and none of the independent variables tested were significant.

In the cases where the experience curve model did give a significant fit, the dependent variable was also significantly correlated with each of time and volume of output. (See Table D.25).

In no case did inclusion of a further variable significantly improve the fit of the model.

c) Notes on slopes of experience curve model fitted to data. It was noted that data for the period 1968-77 (eg data for direct cost per unit) was fitted by an experience curve model with a 'steeper' slope. For example for syphons, total cost per unit 1957-77 was fitted by a curve with slope 88.3%, whereas direct cost per unit was fitted by a curve with slope 72.9%.

When unit price and total cost data was tested over the same period, both sets were fitted by experience curve models with steeper slopes (69.8% and 67.3% respectively, see Table D.24). This was also found to be true for data for bulbs (Table D.25).

The reason for this is not because the rate of reduction in unit cost or average price increased in the later period, but due to the fact that price and cost data was equally (or more) well fitted by a linear model with cumulative output. This will be demonstrated by a simulated case:

If the relationship between unit cost and cumulative output is linear, then eg

unit cost = £100 when cumulative output = 1000

" " = £ 80 " " " = 2000

may be expressed by the equation

$$y = 120 - \frac{20}{1000}x \quad \text{where } x = \text{cumulative output}, \; y = \text{unit cost}$$

Thus, when cumulative output = 4000,

unit cost = £40

If this same data is fitted by an experience curve model, the first two data points would give an experience curve 'slope' of 80%, whereas the second two would give a 'slope' of 50%

$$\left[\frac{\text{Unit cost at time t2}}{\text{Unit cost at time t1}}\right] = \left[\frac{\text{Cum output at time t1}}{\text{Cum output at time t2}}\right]^b$$

ie. $\left[\frac{40}{80}\right] = \left[\frac{2000}{4000}\right]^b$

$\Rightarrow b = 1$

$\Rightarrow$ 'slope' of curve $= \frac{1}{2^b} = .50$ or 50%

Implications of this are as follows:

If data is equally well-fitted by a linear model, then

i) Slopes of experience curve models fitted to subsets of the same set of data will vary according to the period covered by the subset.

ii) If slopes of models for two different sets of data are being compared, then data should cover approximately the same period of time.

1.3.2 Analysis of data for six categories of machine

Six categories of machine

i) Data

The data consisted of annual sales value and volumes for each of the machines chosen. Unfortunately data was only available for the years 1972-77. Previous to this the information is included in a much wider category.

Sales are those of UK manufacturers; a return is compulsory for companies employing more than 25 employees.

Deflating Index

The deflating index is the same as that used for arc-welding equipment, ie the index of home sales of manufactured goods, 1970 = 100.

Data See Tables D.26 and 27

Cumulative output

In the first two cases (Floor mounted drilling machines, and sawing and cutting off machines), and in the second type of pump, these were calculated from the average compound growth rate over the period of available data, as has been previously explained.

In the cases of turning machines, bending and forming machines, and the first type of pump, estimation of best straight lines through the data for output volumes produced evidence of an overall decline in volume. Cumulative output was then estimated on the basis of a average output being steadily produced over the previous twenty years.

ii) <u>Results</u> See graphs D.29-31 and Table D.28

In no case was average price significantly correlated with cumulative output, on a log/log model. The graphs show the wide spread of points and demonstrate that any correlation between the two is unlikely (Graphs D.29-31).

Correlation between average price and output volume was tested in each case, and was significant in two cases, for sawing and cutting-off machines and pumps, single stage. (See Table D.28).

iii) Since all sets of data contained only six data points, only those giving significant correlation with volume are included in the final analysis.

Table D.20

Data for Soda Syphons, 1967/68 - 1976/77

	1976/77	75/76	74/75	73/74	72/73	71/72	70/71	69/70	68/69	67/68
Volume Units	350,721	367,543	327,331	397,513	423,597	417,367	383,750	375,155	372,086	388,086
Cumulative Volume 000	6989.7	6639.0	6271.5	5944.2	5546.6	5123.0	4705.7	4321.9	3946.8	3574.7
ACTUAL VALUE £										
Price (Each)	5.208	4.122	3.808	2.973	2.674	2.697	2.581	2.543	2.457	2.337
Cost per unit										
Direct	2.814	2.185	2.007	1.575	1.348	1.406	1.308	1.210	1.306	1.234
Fixed	2.281	1.684	1.500	1.210	1.065	1.275	1.259	1.170	1.193	.989
Total	5.095	3.869	3.507	2.785	2.413	2.681	2.567	2.380	2.499	2.223
Deflating Index	255.3	218.6	188.7	152.0	123.2	114.8	109	100	93.4	89.9
DEFLATED VALUE £										
Price (Each)	2.016	1.886	2.018	1.956	2.170	2.349	2.368	2.543	2.631	2.600
Cost per unit										
Direct	1.102	1.000	1.064	1.036	1.094	1.225	1.200	1.210	1.398	1.373
Fixed	.893	.770	.795	.796	.864	1.110	1.155	1.170	1.278	1.100
Total	1.995	1.770	1.859	1.832	1.958	2.335	2.355	2.380	2.676	2.473

Table D.21

Data for Soda Syphons, 1955/56 - 1966/67

1966/67	65/66	64/65	63/64	62/63	61/62	60/61	59/60	58/59	57/58	56/57	55/56
347,725	377,523	284,288	191,723	146,992	139,641	132,521	109,887	93,213	104,497	79,602	86,321
3186.6	2838.9	2461.4	2117.1	1985.3	1838.3	1698.7	1566.2	1456.3	1363.1	1258.6	1179.0
2.375	2.347	2.397			2.345	2.368	2.246	2.268	2.196	2.208	
1.779 0.484 2.263	1.667 0.430 2.097	1.664 0.632 2.296			1.454 0.433 1.887	1.542 0.464 2.006	1.599 0.516 2.115	1.522 0.436 1.958	1.378 0.330 1.708	1.462 0.333 1.795	
86.5	85.6	83.3	80.3	78.0	77.0	75.3	73.3	72.35	72.16	71.64	
2.746	2.742	2.878			3.045	3.145	3.064	3.134	3.043	3.083	
* 2.057 0.560 2.617	1.947 0.503 2.450	1.998 0.759 2.757			1.889 0.562 2.451	2.048 0.616 2.664	2.182 0.704 2.886	2.104 0.603 2.707	1.910 0.458 2.368	2.041 0.465 2.506	

* N.B. Categories change - Direct cost now contains manufacturing fixed cost

Table D.22.

Data for Syphon Bulbs, 1967/68 - 1976/77

	1976/77	75/76	74/75	73/74	72/73	71/72	70/71	69/70	68/69	67/68
Volume Units 000	40,527	43,235	47,371	43,411	41,157	46,239	39,656	37,903	33,236	29,518
Cumulative Volume Million	631.3	590.8	547.6	500.2	457.8	415.6	369.4	329.7	291.8	258.6
ACTUAL VALUE P										
Price (Each)	5.23	4.33	3.86	2.96	2.52	2.20	2.14	2.11	1.88	1.84
Cost per unit										
Direct	2.707	2.551	2.056	1.513	1.212	1.183	1.049	0.908	0.761	0.742
Fixed	1.668	1.244	1.058	.864	.731	.740	.782	.744	.761	.694
Total	4.375	3.795	3.114	2.377	1.943	1.923	1.831	1.652	1.522	1.436
Deflating Index	255.3	218.6	188.7	152.0	123.2	114.8	109	100	93.4	89.9
DEFLATED VALUE P										
Price (Each)	2.05	1.98	2.04	1.95	2.05	1.92	1.96	2.11	2.01	2.04
Cost per unit										
Direct	1.061	1.167	1.090	0.996	0.984	1.030	0.962	0.908	0.815	0.825
Fixed	.653	.569	.560	.568	.594	.644	.717	.744	.815	.772
Total	1.714	1.736	1.65	1.564	1.578	1.674	1.679	1.652	1.630	1.597

Table D.23.

Data for Syphon Bulbs, 1955/56 - 1966/67

1966/67	65/66	64/65	63/64	62/63	61/62	60/61	59/60	58/59	57/58	56/57	55/56
24,545	27,714	20,974	17,327	16,385	14,572	12,092	11,456	11,746	11,810	10,045	8,375
229.1	204.5	176.8	155.8	138.5	122.1	107.6	95.4	84.0	72.3	60.5	50.4
1.830	1.765	1.778			1.740	1.759	1.755	1.751	1.776	1.782	
1.372	1.253	1.235			1.079	1.145	1.250	1.176	1.115	1.180	
0.313	0.267	0.399	0.335	0.246	0.195	0.252	0.233	0.177	0.162	0.144	
1.685	1.520	1.634			1.274	1.397	1.483	1.353	1.277	1.324	
86.5	85.6	83.3	80.3	78.0	77.0	75.3	73.3	72.35	72.16	71.64	
2.116	2.062	2.135			2.259	2.336	2.395	2.420	2.461	2.487	
1.586	1.464	1.482			1.401	1.521	1.705	1.625	1.545	1.647	
0.362	0.312	0.479	0.417	0.316	0.253	0.334	0.318	0.244	0.225	0.201	
1.948	1.776	1.961			1.654	1.855	2.023	1.870	1.770	1.848	

Table D.24. Results of analyses on data for syphons

Dependent Variable	Time Period	Test of exp. curve model			Multiple Regression Test			Incl. of further variable
		Corr Coeff	Sig. level	Slope of curve	V_1 Time	V_2 Volume	V_3 Cum. Output	
Unit price	1956–71	–0.94	.01%	82.4%	R^2=92.9 (.01%)	R^2=62.6 (0.1%)	R^2=97.4 (.01%)	Not sig. at 5%
Unit price	1956–67	–0.90	0.1%	90.3%				
Unit price	1968–77	–0.95	.01%	69.8%	R^2=89.7 (0.1%)	R^2=10.3 (not sig)	R^2=91.0 (.01%)	Not sig. at 5%
Total unit cost	1957–77	–0.92	0.1%	88.3%	R^2=58.2 (0.1%)	R^2=26.2% (2.5%)	R^2=69.4 (.01%)	Not sig. at 5%
Total unit cost	1968–77	–0.89	0.1%	67.3%	R^2=67.6 1.0%	R^2=15.0% not sig. at 5%	R^2=79.5% 0.1%	Incl. of V_1 with V_3, at 5%
Direct cost/ unit	1968–77	–0.91	.04%	72.9%	R^2=78.5 0.1%	R^2=2.86% not sig. at 5%	R^2=79.7% 0.1%	Not sig. at 5%
Fixed cost/ unit	1968–77	–0.84	0.1%	61.3%	R^2=70.7 (1.0%)	R^2=4.6% not sig. at 5%	R^2=72.5 (0.1%)	Incl. of V_1 with V_3 at 5%

Table D.25. Results of analyses on data for bulbs

Dependent Variable	Time Period	Test of exp. curve model			Multiple Regression Test			Incl. of further variable
		Corr Coeff C	Sig. level	Slope of curve	V_1 Time	V_2 Volume	V_3 Output	
Unit price	1956–77	–0.92	0.1%	93.2%	R^2=89.3 (.01%)	R^2=89.5 (.01%)	R^2=73.3 (0.1%)	Not sig.
Unit price	1968–77	–0.14	not sig. at 5%	–	R^2=1.4 not sig. at 5%	R^2=14.0 not sig. at 5%	R^2=1.2 not sig. at 5%	–
Total Unit Cost	1956–77	–0.62	1.0%	95.8%	R^2=36.6 (1.0%)	R^2=45.8 (0.2%)	R^2=34.1 (1.0%)	Not sig.
Total Unit Cost	1968–77	C = 0.38	not sig. at 5%	–	–	–	–	–
Direct cost per unit	1968–77	+0.92	0.1%	122.7%	R^2=82.4 (0.1%)	R^2=82.7 (0.05%)	R^2=71.1 (1.0%)	Not sig.
Fixed cost per unit	1968–77	0.86	0.1%	79.4%	R^2=68.7 (1.0%)	R^2=72.2 (0.2%)	R^2=68.2 (1.0%)	Not sig.

DATA: Other Industries Table D.26

Floor Mounted Drilling m/c

	77	76	75	74	73	72
No (units)	5085	4520	4186	4210	3804	4199
Value(£'000)	5703	5309	4026	2526	2307	2459
Defl val.	2208	2428	2133	1662	1873	2142
Defl Price (£)	434.2	537.2	509.6	394.8	492.3	510.1
Cum output	120725	115640	111120	106934	102724	98920
Log output	5.082	5.063	5.046	5.029	5.012	4.995
Log price	2.638	2.730	2.707	2.596	2.692	2.708
Sawing and Cutting off Machines						
No (units)	4717	7113	6269	6387	6260	3748
Value(£'000)	5501	4172	3416	3700	2862	1791
Defl val.	2130	1908	1810	2434	2323	1560
Defl Price (£)	451.6	268.2	288.7	381.1	371.1	416.2
Cum output	135857	131140	124027	117758	111371	105111
Log output	5.133	5.118	5.093	5.071	5.047	5.022
Log price	2.655	2.428	2.460	2.581	2.569	2.619
Turning Machines						
No (units)	5444	5533	8400	6188	6510	6412
Value(£'000)	4365	3420	5003	3655	2984	2354
Defl val.	1690	1564	2651	2405	2422	2050
Defl Price (£)	310.4	282.7	315.6	388.7	372.0	319.7
Cum output	152075	146631	141098	132699	126510	120,000
Log output	5.182	5.166	5.149	5.123	5.102	5.079
Log price	2.492	2.451	2.499	2.590	2.570	2.505

Table D.27

Data: Bending and Forming Machines

	77	76	75	74	73	72
NO (units)	4301	6059	6117	5343	6149	6533
Value(£'000)	3890	3750	2979	2624	1603	2581
Defl val.	1506	1715	1579	1726	1301	2248
Price (£)	350	283	258	323	212	344
Cum output	147969	143668	137609	131492	126149	120,000
Log output	5.170	5.157	5.139	5.119	5.101	5.079
Log price	2.544	2.452	2.412	2.509	2.325	2.537

Pumps Single stage, single entry impeller coupled. Above 6" Discharge outlet

	77	76	75	74	73	72
No (units)		1352	1634	1221	1301	3018
Value(£'000)		4247	3777	2867	1994	2950
Defl val.		1943	2002	1886	1618	2570
Price (£)		1437	1225	1545	1244	852
Cum output		45508	44156	42522	41301	40,000
Log output		4.658	4.645	4.629	4.616	4.602
Log price		3.157	3.087	3.189	3.095	2.930

Pumps (Excl hydraulic) positive displacement, reciprocating pumps. Power operated other than steam

	77	76	75	74	73	72
No (units)		5391	7164	4976	3445	2577
Value(£'000)		4127	3093	1451	971	961
Defl val.		1888	1639	955	788	837
Price (£)		350	229	192	229	325
Cum output		34582	29191	22027	17051	13606
Log output		4.539	4.465	4.343	4.232	4.134
Log price		2.544	2.359	2.283	2.359	2.512

Table D.28

Results of tests on data from other industries

Linear regression tests were performed on the correlation between data for deflated price and cumulative output, and deflated price and volume.

Results are given in the table below.

	Log/log Model				Linear Model		
	CUMULATIVE OUTPUT VOLUME						
	Corr Coeff C	F ratio	Sig Level	Slope of Curve	C	F ratio	Sig Level
1) Floor mounted drill machine	-.129	.067	NOT sig at 5%		-.24	.24	NOT sig at 5%
2) Sawing & cutting-off machine	-.263	.298	NOT sig at 5%		-.78	6.23	10%
3) Turning machines	-.519	1.47	NOT sig at 5%		.106	.045	NOT sig at 5%
4) Pumps(excl. hydraulic)posi. displacement reciprocating pumps excl. steam	.059	.01	NOT sig at 5%		-.271	.238	NOT sig at 5%
5)Pumps, single stage single entry impeller coupled	.67	2.45	NOT sig at 5%		-.915	15.45	2.5%
6) Bending & Forming machines	.15	.09	NOT sig at 5%		-.472	1.14	NOT sig at 5%

1.3.3 Passenger cars

Data is given for sales of passenger cars; four wheel (including taxis, station wagons and estate cars). Sales by UK manufacturers as before.

Data available for 1954, 58, 63, 68, and 1973-77 inclusive.

Deflating Index ; Wholesale prices of all manufactured products.

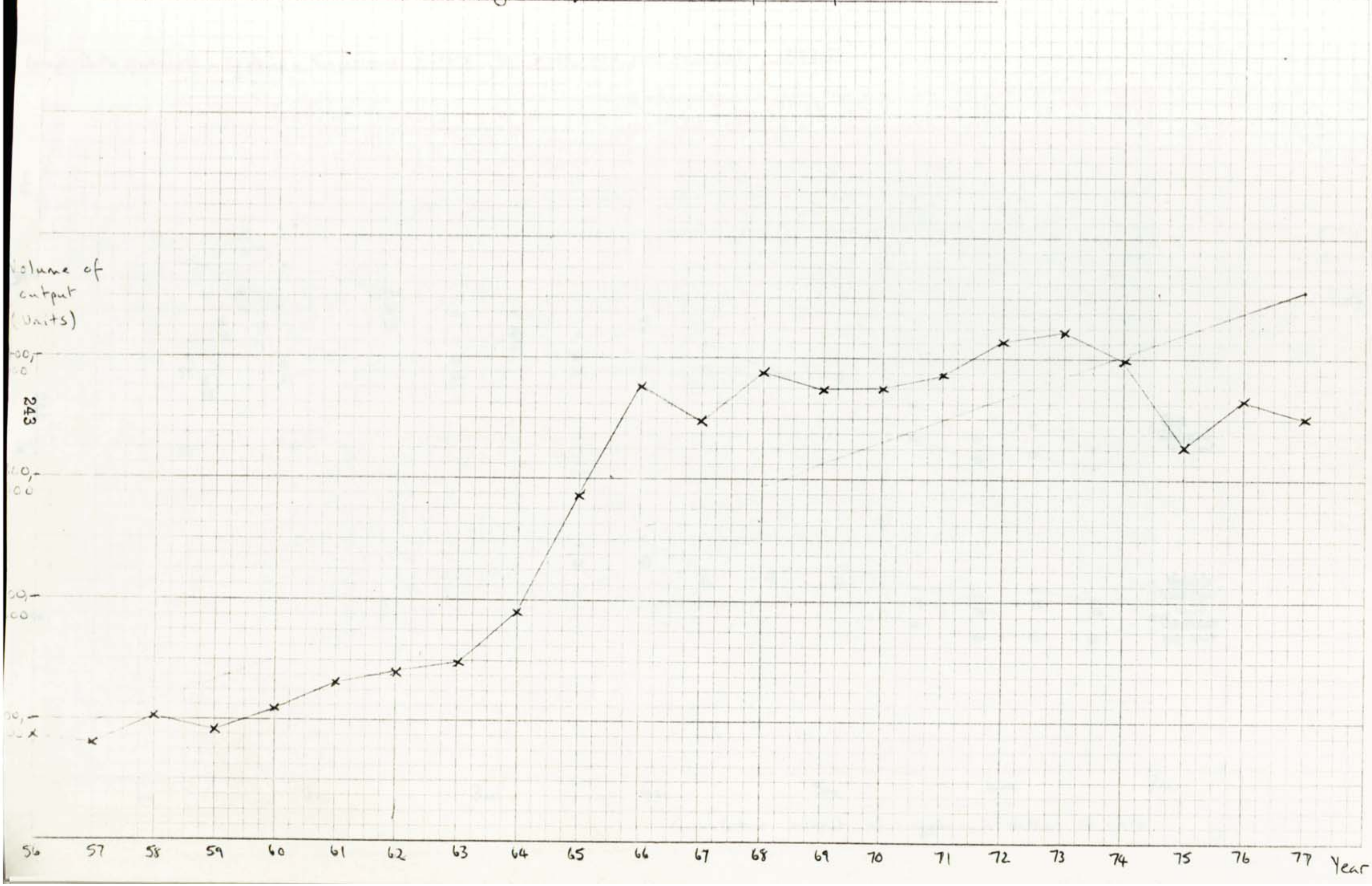
Cumulative output estimated from average compound growth rate over the period 1954-68, since over this period volumes are increasing, subsequently decrease. Average compound growth rate 1954-68 is 7.07% p.a.

Table D.29

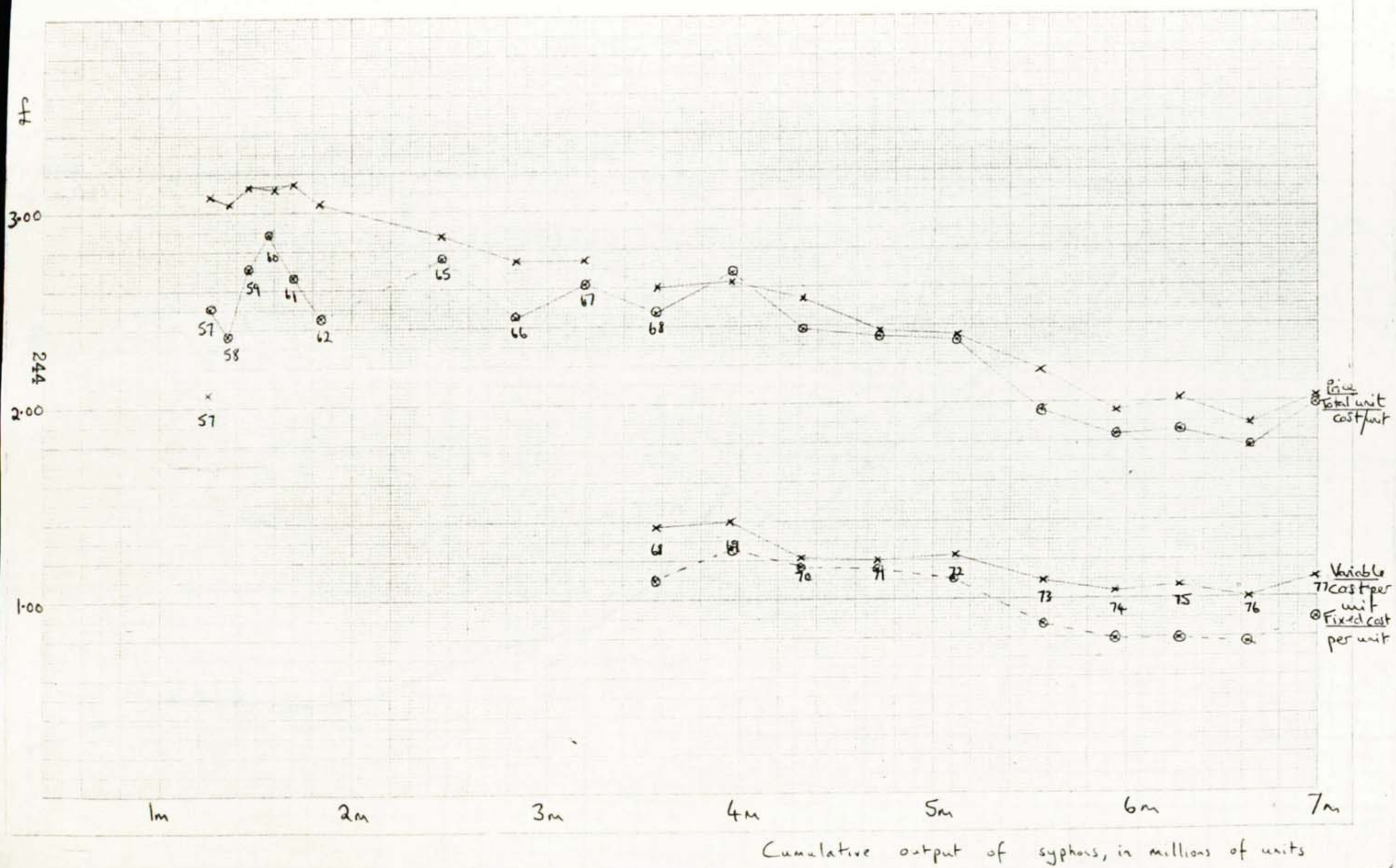
Data

	Value £000	Volume units 000	Deflating Index	Defl. Value £'000	Defl. Price £	Cum. Output
1954	257.5	718.7	64.9	396.76	552.1	10176.1
1958	413.6	1030.5	72.16	573.17	556.2	11206.6
1963	644.8	1508.5	78.0	826.67	548.01	12715.1
1968	853.2	1851.8	89.9	949.05	512.5	14566.9
1973	1248.7	1786.8	123.2	1013.6	567.3	16353.7
1974	1417.7	1562.5	152.0	932.70	596.93	17916.2
1975	1445.2	1293.0	188.7	765.87	592.3	19209.2
1976	2046.0	1384.1	218.6	935.96	676.2	20593.3
1977	2312.2	1265.1	255.3	905.68	715.90	21858.4

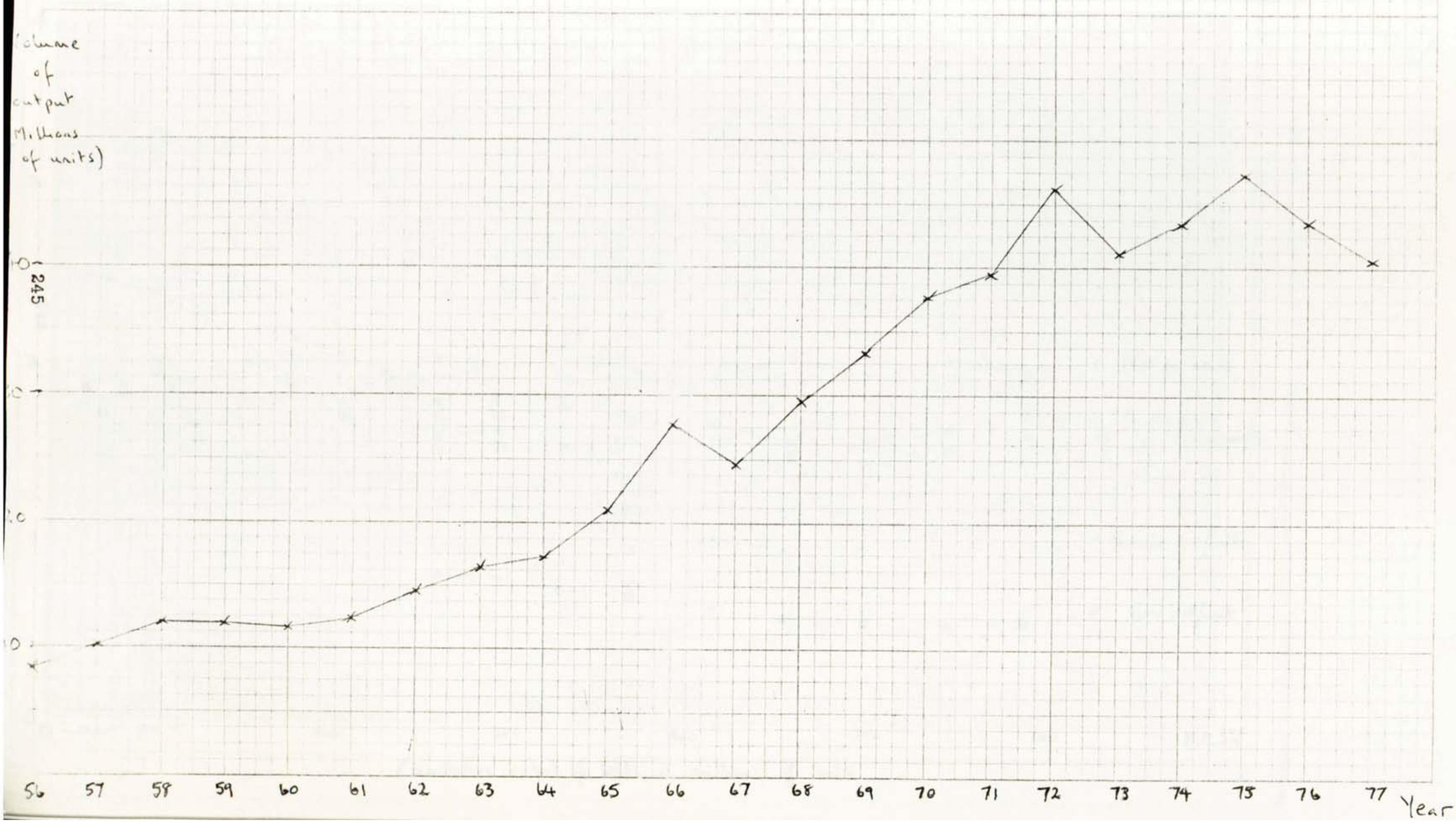
Graph D.25 SPARKLETS – Syphons, Volumes of output 1956–77



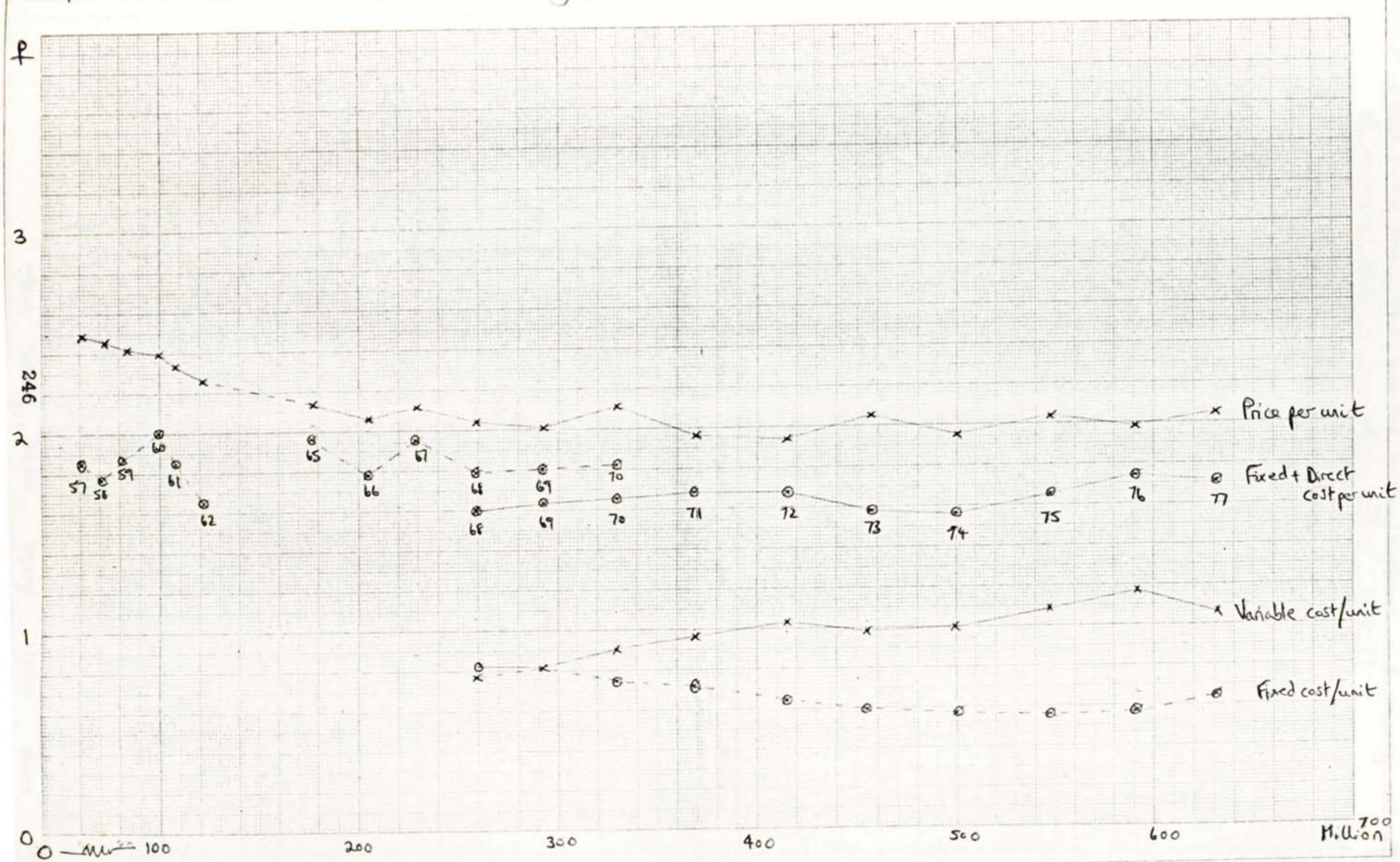
Graph D.26 SPARKLETS – Syphons. Experience curves (for price and cost per unit) 1957–77



Graph D.27 SPARKLETS - Bulbs, Volumes of output 1956-77



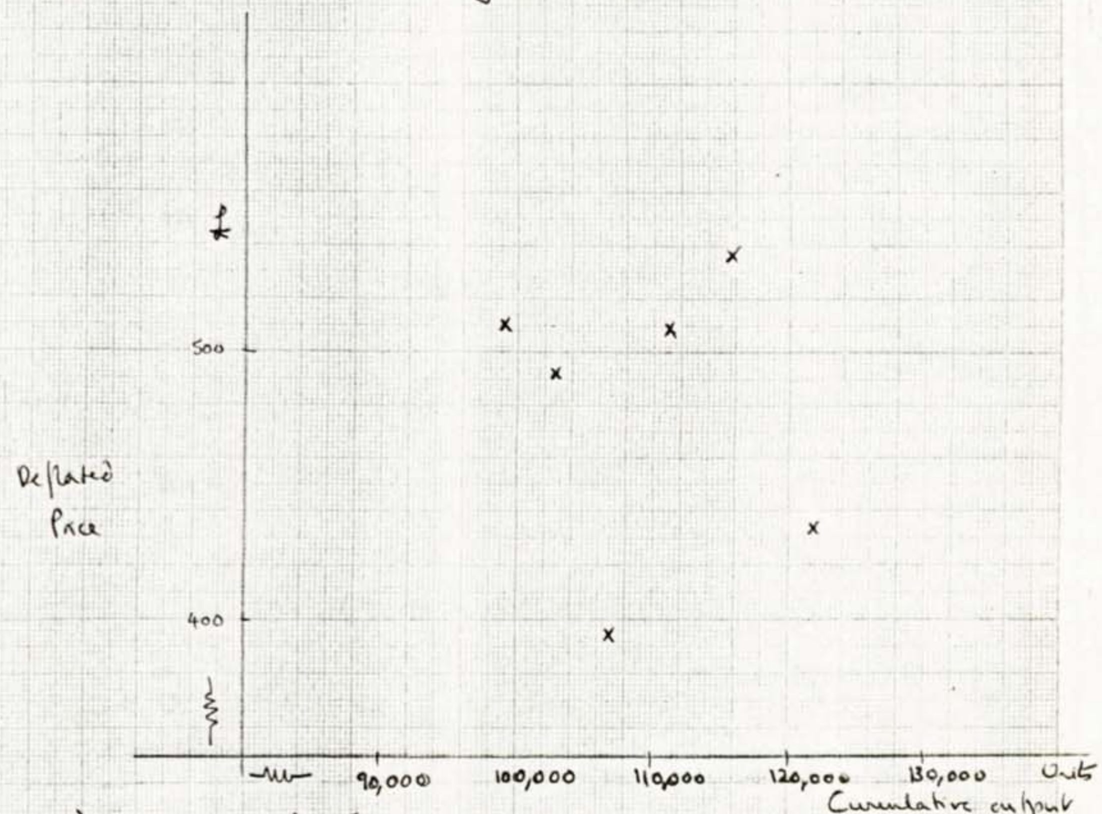
Graph D.28 SPARKLETS - Bulbs Experience curves for price and cost per unit 1957-77



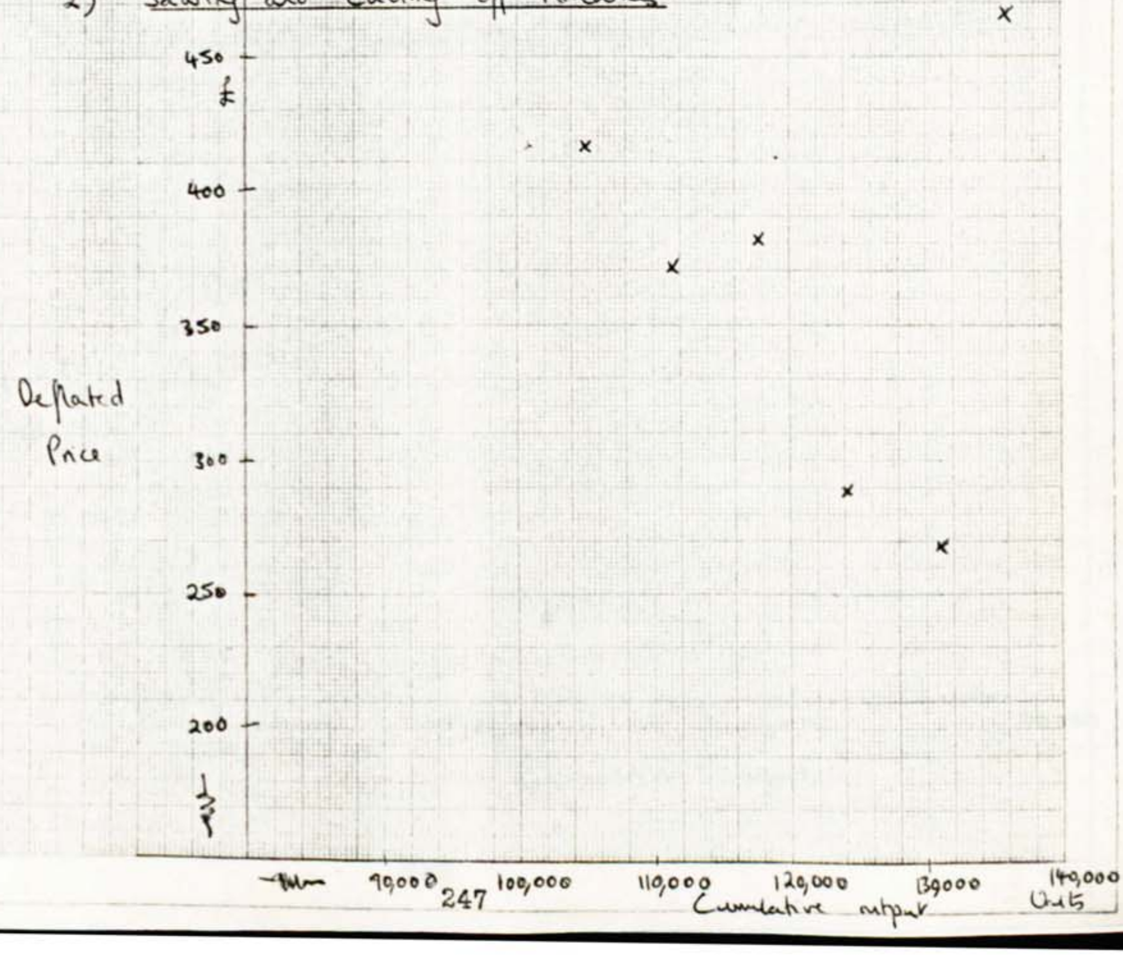
Cumulative output of bulbs, in millions of units

Graph D.29 OTHER INDUSTRIES ; Floor mounted drilling machines and sawing and cutting off machines, price v cumulative output : 1972-77

1) Floor Mounted drilling machines

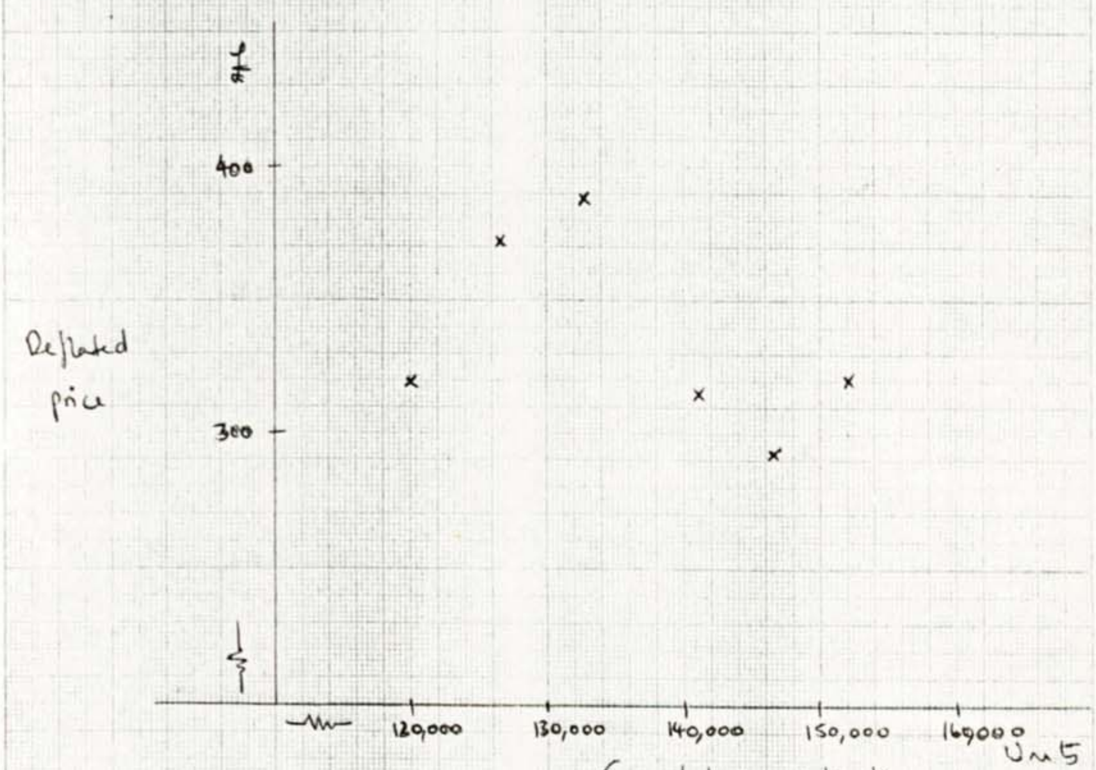


2) Sawing and Cutting Off Machines

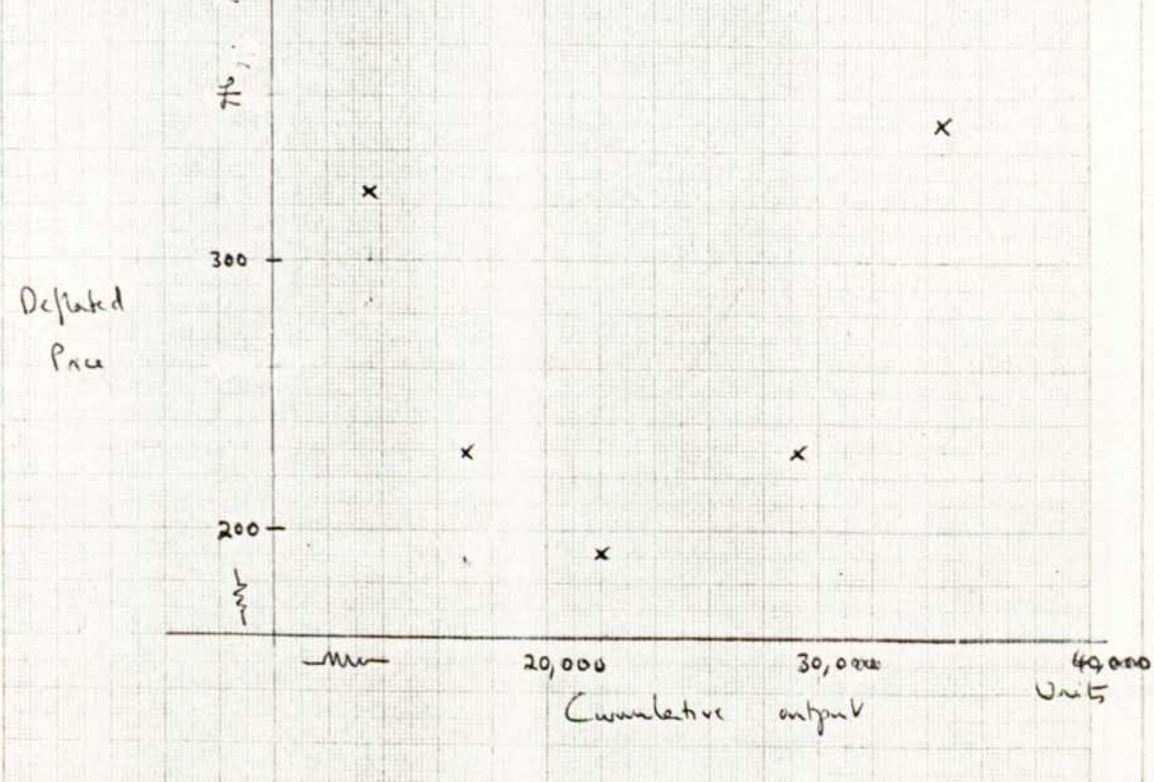


Graph D.30 OTHER INDUSTRIES : Turning machines and pumps (Type I), price v cumulative output, 1972-77

3) Turning machines

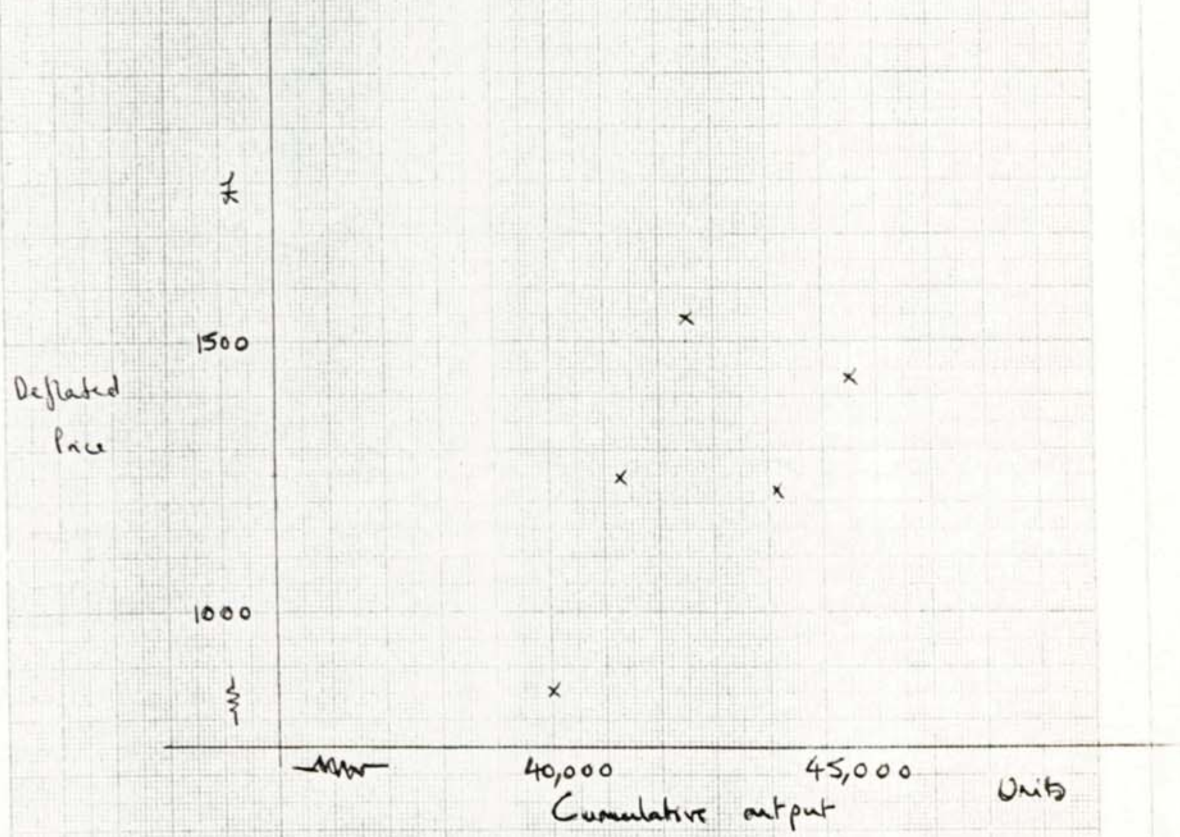


4) Pumps (Excluding Hydraulic) positive displacement, reciprocating

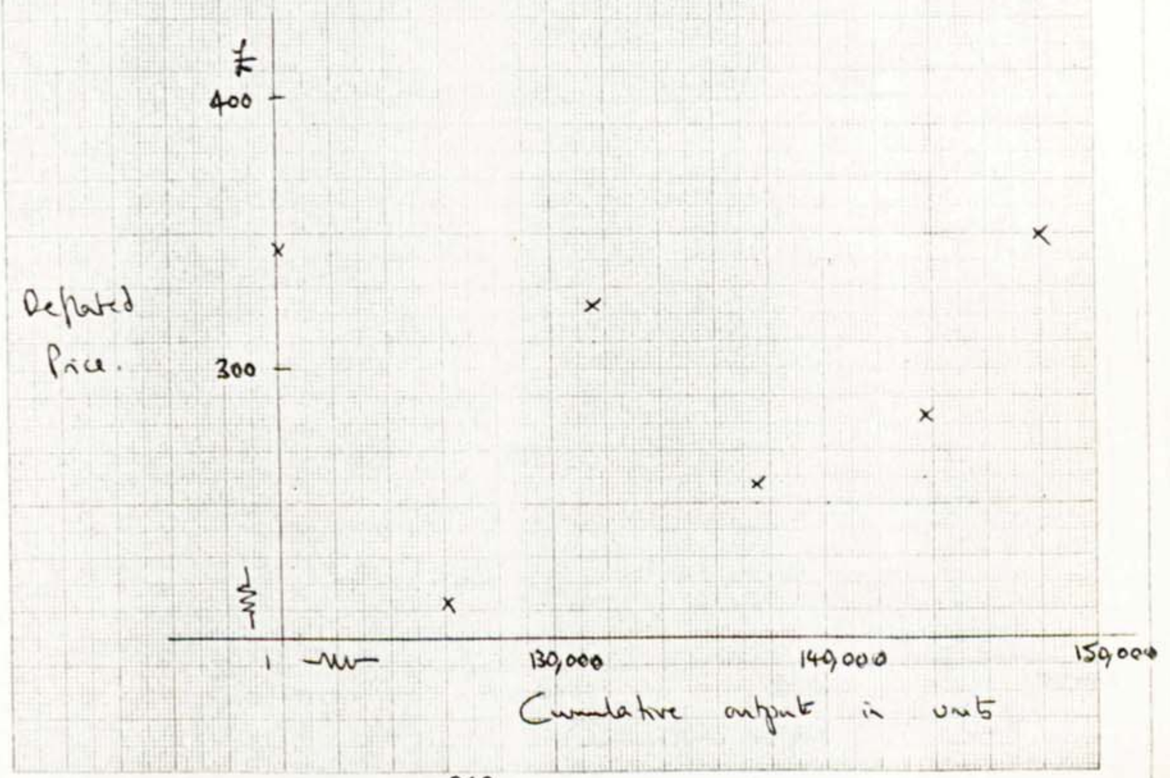


Graph D.31 OTHER INDUSTRIES ; Pumps (Type II) and bending and forming machines, Price v cumulative output, 1972-77

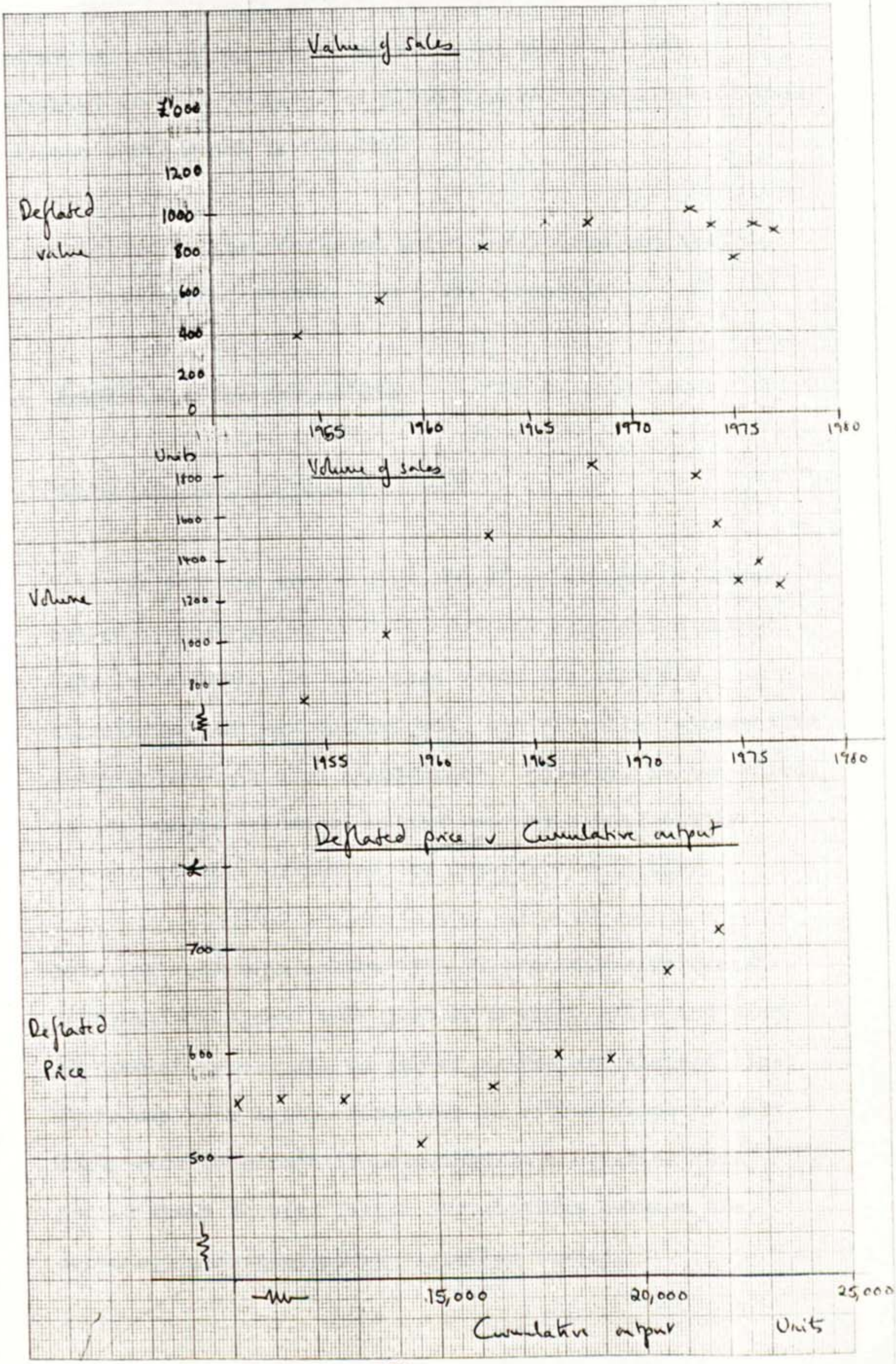
5) Pumps, Single stage, single entry impeller coupled.



6) Bending and forming machines



Graph D.32 Passenger cars : Sales by UK manufacturers, 1954-77



Results

Clearly from the graph , (D.32) the deflated price has shown a fairly steady increase over the period 1954-77. (Except for a drop in 1968). The data of deflated price and cumulative output correlate on a log/log model. with C = +0.76, F = 9.61, significant at a 97.5% level of significance. The slope of this experience curve model is 102.26%

The correlation between deflated price and volume was tested, but was found insignificant. C = -.15, F = .15.

1.3.4 Summary - Other Industries

a) Sparklets soda syphons and bulbs

Data for syphons gave a significant relationship between either average price or unit cost and cumulative output (log/log model). In all cases where the multiple regression test was carried out, the variable representing elapsed time was also significant. However, in two-thirds of the cases, volume of output was not significantly correlated with either of the dependent variables.

Data for bulb manufacture 1956-77 produced significant correlation between unit cost or average price and each of cumulative output, volume of output and elapsed time. There was very little variation in either price or unit cost over the period 1968-77, and data covering this period shows no significant correlations between the dependent and independent variables tested.

b) Six types of machine

Results

The data for the six types of machine, drilling machines, sawing and cutting off machines, turning machines, bending and forming machines, and two types of pump gave results:

a) No correlation between deflated price and cumulative output.

b) Correlation between deflated price and output volume in two cases; sawing and cutting-off machines (significant at 95%), and pumps single stage, single entry impeller coupled (significant at 97.5%).

Data

Data is over a 6 year time period only. In no case does price show a steady decline, is generally very erratic, and often peaks in some years.

c) Passenger cars

Deflated price has increased over the time period 1954-77, with a drop in 1968.

Data gives a correlation between deflated price and cumulative output on a log/log model, with a positive experience curve slope of 102%.

There is no correlation between deflated price and volume.

1.4 Results and Conclusions (Tables 6.1 and 6.2 in main text)

Of the original 32 sets of data, 14 were excluded as the lack of significant results could have been due to the inadequacies of the data, either that there were too few data points or that the validity of the data was suspect. (Table 6.1)

The results of the remaining 18 sets are shown in Table 6.2

These demonstrate that, although the dependent variable is frequently significantly correlated with cumulative output, in all cases it is significantly correlated with at least one other independent variable. In some cases the correlations with other variables give higher values of R^2, indicating a higher goodness of fit.

In some cases the linear form of the model gives higher value of R^2 than does the log/log model.

Thus the conclusion is that the evidence does not support the contention that the experience curve is the only, or the best model, in individual cases.

However, in order to decide whether or not it is the best model overall, a measure of the error of fit is required. The difference between choosing one uniform model or the best one in each case can then be measured using the percentage difference in error of fit.

This experiment is reported in D.2

D.2 Measurement of error of fit

For each model fitted, the standard deviation of error measures the inverse of goodness of fit of the model. Hence this criterion can be used to compare choice of different models for each set of data.

If standard deviation of error = S

$$S^2 = \frac{\text{Total Sum of squares} \times (1-R^2)}{(n-2)}$$

Where R^2 is the proportion of variation in the dependent variable explained by the regression.

In comparing standard deviations for two different models fitted to the same set of data, the total sum of squares and the value of n will be the same. (n is the number of data points).

Thus

$E = \sqrt{1-R^2}$ is sufficient to compare standard deviation of error between two models for the same data set.

The variable giving the best fit will be that with the least value of E. Let this be variable V_b, with $E = Ev_b$.

Then, the percentage worsening of error from a model containing a different variable, Vi say, over that for the best variable V_b will be

$$\frac{Evi - Evb}{Ev_b} \times 100$$

ie $\dfrac{\text{Increase in standard error using } V_i \text{ over vb}}{\text{Standard deviation of error of } V_b} \times 100$

The result of this for each data set and each independent variable are shown in table D.31.

NB. All are calculated from values of R^2 obtained in fitting a linear model involving one independent variable, except for UK arc welding equipment and BOC data for unit cost and average price for which the best model was chosen in each case.

In addition, for the UK arc welding equipment industry average price, and BOC Arc Equipment unit cost, the percentage worsening of error is calculated for choice of each form of the model involving each independent variable, over the best in each case.

Results

See Tables D.32, 33 and 34 for summary of results.

These show that the percentage worsening of error if a uniform variable is chosen would be considerable.

For the variable elapsed time, average percentage worsening of error $= \dfrac{429.375}{18} = 23.85\%$, with the maximum increase being 101%.

For volume of output, average percentage worsening of error is $\dfrac{811.6}{18} = 45.09\%$, with maximum worsening of 280%.

For cumulative output, the average percentage worsening is

$\frac{408.1}{18} =$ 22.67%, with maximum worsening of 102%.

Conclusion

In view of the average percentage worsening of error if one uniform variable is chosen for the model, the recommended model must be the one which best fits the data, in each case.

Table D.32 Table giving details of error of fit in each case

$E = \sqrt{1-R^2}$ where R is the proportion of sum of squares due to the regression.

$$\text{Standard deviation of error} = \frac{\text{total S.S} \times \sqrt{1-R^2}}{n-2}$$

Thus E is sufficient for comparing the ratio of standard deviation of error from one variable to another % worsening of error of variable Vi over 'best', say Vb

$$= \frac{Evi - Evb \times 100}{Evb}$$

$$= \frac{\text{Increase in standard dev}^n \text{ of error using vi}}{\text{Standard dev}^n \text{ of error of vb}}$$

	E = Error			% Worsening over best		
	Time	Vol.	Cum Output	Time	Volume	Cum Output
UK price Linear	.444	.450	.401	10.7	12.2	0
BOC price log/log	.695	.520	.679	33.6	0	30.6
BOC cost log/log	.796	.574	.777	38.7	0	35.4
France	.594	.907	.591	.5	53.5	0
Germany weld m/cs	.551	.972	.533	3.2	82.4	0
" DC Rects.	.404	.814	.475	0	101.5	17.6
Japan DC Welders	.672	.989	.672	0	47.2	0
Japan Arc w.m/cs	.981	,981	.989	0	0	.8
Belge-Lux Exps	.990	.493	.997	100.8	0	102.0
Netherland	.512	.456	.476	12.3	0	4.4
" Exps	.417	.951	.458	0	128.1	9.8
Syphons Price	.266	.611	.161	65.2	279.5	0
Syphons cost	.646	.860	.553	16.8	55.5	0
Bulbs Price	.327	.324	.517	.925	0	59.6
Bulbs Cost	.796	.736	.812	8.15	0	10.3

Table D.31 cont.

	Time	Vol.	Cum Output	Time	Volume	Cum Output
Sawing & cutting off machines price	.964	.626	.964	54.0	0	54.0
Pumps	.741	.404	.741	83.4	0	83.4
Cars	–	.989	.650	–	52.1	0
			TOTAL	429.375	811.6	408.1

Table D.33 Comparison of standard deviation of error obtained from fitting different models to data for BOC Arc Equipment, Unit cost of a rectifier.

Error $E = \sqrt{1-R^2}$

Form of model	Time	Volume	Cum Output
		Values of E	
Linear	.806	.613	.811
Log/Linear	.721	.582	.782
log/log	.796	.574	.777
Percentage worsening of error for choice of variable, for each form of model			
		% worsening of error	
Linear	31.5	--	32.3
Log/Linear	23.8	-	34.4
Log/log	38.7	-	35.4
Percentage worsening of error for choice of form of model, for each variable.			
		% worsening of error	
Linear over log/log	1.26	6.79	4.38
Log/linear over log/log	-9.4	1.39	6.43
Percentage worsening of error for choice of each over the overall best, ie Log/log model with volume			
		% worsening of error	
Linear	40.4	6.8	41.3
Log/linear	25.6	1.39	36.2
Log/log	38.7	-	35.4

Table D.34 Comparison of standard deviation of error obtained from fitting different models to data for UK arc welding equipment industry average price of a rectifier.

Error $E = \sqrt{1-R^2}$

Independent Variable

Form of model	Time	Volume	Cum Output
		Value of E	
Linear	.444	.450	.401
Log/linear	.559	.466	.448
Log/log	.592	.485	.454
Percentage worsening of error for choice of single variable, for each form of model			
		% worsening of error	
Linear	10.7	12.2	-
Log/linear	24.8	4.0	-
Log/log	30.4	6.8	-
Percentage worsening of error for choice of form, for each variable. (Single)			
		% worsening of error	
Log/linear over linear	25.9	3.6	11.7
Log/log over linear	33.3	7.8	13.2
Percentage worsening of error for choice of each over the overall best, ie. linear model with cumulative output as independent variable			
		% worsening of error	
Linear	10.7	12.2	-
Log/linear	39.4	16.2	11.7
Log/log	47.6	20.9	13.2

D.3 Estimates of the accuracy of prediction for models for UK industry average price and BOC Arc Equipment unit cost

Since strategic plans for BOC Arc Equipment are made each year, for the following five year period, the accuracy of prediction is important over this period.

For this reason, the accuracy of prediction of UK average price and BOC unit cost are examined for the end of the period 1977-82, ie after five years.

The predicted value for each of average price and unit cost can be calculated from respective time-related models, for the year 1982. However, for volume or cumulative output related models this requires prediction of output volumes over the whole period.

The volumes predicted are thus an additional source of error for predicted price or unit cost.

In order to examine the extent to which errors in volume prediction affect errors in unit cost prediction for BOC Arc Equipment, a correct volume growth rate of 10% p.a. is assumed for the output of the company. The predicted unit cost and 95% confidence limits from the correct volume is then compared with unit cost predicted from predicted volumes which are wrong, by ± 10%, ± 20%.... ± 50%.

This exercise was performed for the model for BOC Arc Equipment unit cost only, since the results so far suggest that the most accurate model for this is a volume-related log/log model. (See D.2) However, the most accurate model for UK arc equipment industry average price is a linear relationship between average price, and cumulative output. Accuracy of prediction from this model will also depend, to a certain extent, on the accuracy of volume predictions.

Method

Using the best-fitting model in each case, predicted values of the dependent variable (average price or unit cost) were calculated for the five year period, based on a 'correct' volume growth rate of 10% p.a. Values predicted using 'incorrect' estimates of volumes were then compared with 95% confidence limits for the 'true value' of the predicted point.

95% confidence limits for a predicted point are based on the standard deviation of the point, which depends on both the errors of estimation of parameters of the model, and on errors due to the error term.

$$\text{Model} : Y_i = \alpha + \beta x_i + \varepsilon_i \quad (\varepsilon_i \sim N(0, \sigma^2))$$

Where α, β are parameters of the model, and are estimated using the method of least squares, by a and b.

A particular value of y will be estimated by

$$y = a + bx$$

Thus, the standard deviation of error of the predicted point depends on the standard deviation of the predicted point (a+bx), plus the standard deviation of the error term ε

ie, Variance y = variance (a+bx) + variance ε

New variance (a+bx) $= \sigma^2 \left\{ \frac{1}{n} + \frac{(x - \bar{x})^2}{\sum(x - \bar{x})^2} \right\}$

Variance $\varepsilon = \sigma^2$

$\therefore$ Variance y $= \sigma^2 \left\{ 1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{\sum(x - \bar{x})^2} \right\}$

Confidence limits may be calculated in the following way:

σ^2 is estimated by S^2, where

$$S^2 = \frac{\text{Total sum of squares x } (1-R^2)}{(n-2)}$$

Standard deviation of error S^1 for a single point predicted from a particular model is given by

$$S' = S \sqrt{\left\{ 1 + \frac{1}{n} + \frac{(x - \bar{x})^2}{(x - \bar{x})^2} \right\}}$$

The confidence limits for the estimated point are thus given by

$$(a + bx) \pm (t\ \alpha/2,\ n-2 \times S^1)$$

Where a+bx is the predicted point, $t\alpha/2$ is the value of Student's t statistic for 100 (1-x)% level of confidence, and (n-2) degrees of freedom.

D.3.1 Results for model for unit cost for BOC Arc Equipment

If a 10%p.a. rate of volume growth is assumed, volume of output and cumulative output for the period 1978-82 will be as follows

	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
VOLUME	4461	4907	5398	5938	6531	7184
CUM. OUTPUT	66395	71302	76700	82638	89169	96353

The volume and cumulative output for 1981/82 are taken to be the correct values.

Errors in volume prediction are calculated as $\pm$ x% of the 'correct' volume, and cumulative output calculated accordingly.

Standard deviations of error for each model are calculated, ie the value of S which estimates σ for each model, and then the standard deviations of error for predicted unit cost after five years. These are used to estimate 95% confidence limits for the predicted values.

Predicted unit costs are then calculated from each model, for each percentage error in predicted volumes of output. The results are compared with the unit cost and 95% confidence limits predicted using 'correct' volumes. The predicted unit cost under the wrong volume prediction is compared with the extremes predicted by the confidence limits under correct volume prediction, to give possible errors, in percentage terms.

Results

The results are shown in Tables 35 and 36.

Table 35 Predicted unit cost of manufacture for BOC Arc Equipment after 5 years, comparing different models and volume predictions

Error in volume prediction	pred. volume	Pred Cum. Output	Unit Cost predicted by each model* Time	Volume	Cum Output
None (ie 10%p.a. vol growth correct)	7184	96353	480.3 95% CL (350.9,657.5)	426.1 95% CL (331.5,547.7)	480.9 95% CL (355.8,650.0)
+10%	7902	99349	480.3	410.1	477.8
-10%	6466	93357	"	444.5	484.1
+20%	8621	102345	"	396.1	474.9
-20%	5747	90361	"	466.0	487.4
+30%	9339	105340	"	383.5	472.1
-30%	5029	87366	"	491.7	490.8
+40%	10058	108336	"	372.3	469.2
-40%	4310	84370	"	523.0	494.3
+50%	10776	111332	"	362.1	466.6
-50%	3592	81374	"	562.7	498.2

* All using log/log relationships as this gives higher values of R^2 and hence lower standard deviations of error.

Table 36 Comparison of possible errors from predicted unit costs from different models and volume predictions

Each predicted cost is compared with the extremes given by 95% confidence limits for unit cost predicted from correct volumes.

Error in volume prediction	Independent variable in model: Time	Volume	Cum. output
	Possible percent error		
None (correct pred^{n} of 10%p.a. c.g.rate)	(+37%,-27%)	(+28%,-22%)	(+35%,-26%)
+10%	-	(+24%,-25%)	(+34%,-26%)
-10%	-	(+34%,-19%)	(+36%,-26%)
+20%	-	(+19%,-28%)	(+33%,-27%)
-20%	-	(+41%,-15%)	(+37%,-25%)
+30%	-	(+16%,-30%)	(+33%,-27%)
-30%	-	(+48%,-10%)	(+38%,-24%)
+40%	-	(+12%,-32%)	(+32%,-28%)
-40%	-	(+58%,- 5%)	(+39%,-24%)
+50%	-	(+ 9%,-34%)	(+31%,-28%)
-50%	-	(+70%,+ 3%)	(+40%,-23%)

Comparing possible percentage errors in prediction of unit cost from each model (Table 36), it is evident that the following is true:

a) If volume predictions are correct, the error of prediction of unit costs is least with a volume related model (as may be expected from previous work).

b) If errors volume predictions exceed ± 10%, then possible errors in predicted unit cost under a volume related model are greater than those under a time or cumulative output related model.

c) If errors in volume predictions exceed ± 20% then possible errors in predicted unit cost under both the volume and cumulative output related models exceed those made under the time-related model.

D.3.2. Results for model for average price of a rectifier in the UK industry

If a 10% p.a. rate of volume growth is assumed, volume of output and cumulative output for the period 1978-82 will be as follows:

	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82
Volume	6729	7402	8142	8956	9852	10837
Cum Output	68777	76179	84321	93277	103129	113966

These values of volume and cumulative output for 1981/82 were then taken to be the correct ones.

Results

The results of calculating predicted average price after five years, with 95% confidence limits, are given in Table 37. The form of the model used in each case is the linear model.

Table 37 Comparison of predicted UK price of a rectifier in 1982.

	Independent variable in model		
	Time	Volume	Cum Output
Predicted average price	238.19	131.45	127.52
Confidence limits	(173.88,327.27)	((60.20,177.85)	(75.24,163.61)
Poss % error	(+37%,-27%)	(+54%,+35%)	(40%,-28%)

D.3.3 Summary and conclusions

a) Model for unit cost for BOC Arc Equipment

Results of the exercise of predicting unit cost for BOC Arc Equipment from a log/log model, assuming 10% p.a. growth rate in volume over the next Five years shows that errors in predicting unit cost after five years from each independent variable will be

Time	(+37%,-27%)
Volume	(+28%,-26%)
Cum. Output	(+35%,-26%)

However, if errors in volume prediction exceed ±10%, the possible error in predicted unit cost will exceed those obtained from a time related model.

If errors in volume prediction exceed ±20%, possible errors in predicting unit cost from either a volume or cumulative output related model exceed those obtained from a time related model.

Thus the recommended model must be:

Volume related model if errors in volume prediction are likely to be less than ±10%

Cumulative output related model if errors in volume prediction are likely to be between ±10-20%.

Time related model if errors in volume prediction are likely to exceed ±20%.

b) Model for average price for UK industry

Again assuming 10% p.a. growth rate in volume over the next five years, the model with least possible errors in predicting average price is the model including time with cumulative output in a log/linear relationship.

However, if a single variable is required, then a log/linear model with time as independent variable gives less possible error in predicting average price after five years, than does cumulative output.

D.4 Analyses relating to the experience curve model

Many of the supporters of the experience curve model for costs claim that most manufacturing operations should have an experience curve slope of 70-90%, probably around 80%, for their model for unit cost reduction. (See Appendix A, A.1 for definition of experience curve slope. Roughly, it is the percentage reduction in unit cost to be expected for every doubling of cumulative output).

In particular, personel at BOC Arc Equipment wondered if the 81% slope of the experience curve model fitted to average price data for the UK industry, was typical of arc welding equipment industries in comparable manufacturing countries.

In addition, some sets of data spanned long periods of time at least fifteen years, and so these were available for analysis by breaking data down into periods of different volume growth. This could then be used to test the contention of some authors that the type of cost or price reduction modelled by an experience curve only took place in periods of high market growth.

D.4.1 Comparison of experience curve'slopes' from models fitted to different sets of data

The slope of the experience curve model fitted to each set of data, if the relationship was statistically significant, is given in Table 31.

This shows that the parameters of the experience curve models fitted to the different sets of data produced widely differing slopes.

The slopes fitted to data for UK industry average price, BOC average price and unit cost were 81%, 83% and 86.5% respectively.

However, models fitted to data from arc welding equipment industries of different countries had slopes varying from 24.5% (Germany, sales of rectifiers 1970-77), to 161.5% (Netherlands, exports of arc welding machines, 1966-71).

Although much of this data had rather a limited number of data points, referred to wide categories of equipment, or to imports, there was no evidence of a common range of slopes.

Estimation of slope relies on the estimation of cumulative output for the beginning of the data period. Thus, errors in the estimation of cumulative output will affect the slope. However, an exercise which calculates the estimated slope of the fitted model if cumulative output was wrongly estimated by $\pm$ 50%, found that the average difference in slope was only 11-12% (see Table 38). Therefore, the immense variation in slopes of the models fitted cannot be explained by errors in estimated cumulative output at the beginning of each period.

Of the data for other types of industry, the only sets fitted by an experience curve model were data from Sparklets Ltd, and on UK passenger car sales 1954-77.

Data from Sparklets on the manufacture and sales of soda syphons and bulbs was fitted by models with slopes varying from 75% to 96%. The data for bulbs had experienced a lower rate of reduction than that for syphons, ie, slopes were higher.

Data from UK sales of passenger cars showed an overall increase in average price (deflated) over the period 1954-77, giving an experience curve slope of 102%.

Conclusion

The evidence from data tested in this exercise does not support the hypothesis of a common range of slopes for experience curve models fitted in average price or unit cost data in manufacturing industries.

In particular, there appears to be no common slope for models fitted to arc welding equipment industries of different countries.

D.4.2 Investigation of the coincidence of trends in price or unit cost behaviour with periods of differing market growth rates.

Data The data lending itself to analysis of this type, ie consistent data available over a long period of time were sets for:

i) Japan, sales of arc welding machines 1948-70 Table D.15

ii) USA-value of industry shipment and cost of materials per dollar of shipments, 1958-72. Table D.14

iii) Sparklets Ltd, sales of soda syphon bulbs, 1956-77 Tables D.22-23

iv) Sparklets Ltd, sales of soda syphons, 1956-77 Table D.20-21

v) Business monitor, statistics and sales of passenger cars, 1954-77. Table D.29

The method used was to assess differing periods of volume growth from the appropriate graph, divide data into those periods, and test data from each period, separately, to find rate of volume growth and the slope of the experience curve model fitting the data.

The results are shown in Tables D.38and 39

The analyses show no consistent pattern:

a) Japanese data, the experience curve slope is over 100%, indicating increase in average price, for three out of the four periods, one of which had very high volume growth.

b) USA data, the experience curve slope is less than 100% during periods of steady growth or in the decline from 1966-72, and is 111%, indicating rising cost per unit, during the period of high growth 1963-66.

c) Data for Sparklets bulbs shows a 'steep' slope during the early period 1956-65, when growth was steady but a slope of only 93% during the following high growth period.

d) Unit price for syphons shows a gradually declining slope, ie faster rate of reduction in successive periods, even though volume growth slows up and becomes a decline.

e) For passenger cars, the slope of the curve was 87%

when growth was high, but average price has increased during the following periods of no growth and then a decline.

Conclusion

There is no consistent pattern of particular types of average price or cost reduction coinciding with stages in market growth.

The only conclusion to be drawn from this evidence is that there may be a radical change in the rate of price or cost reduction if there is a significant change in volume growth.

Table D. 38 The effect of a ±50% error in estimation of cumulative output (at the start of the period over which data is available) on the estimated slope of the experience curve model

Data Source	Estimated slope of curve: From original estimate of cum. output	Error of -50%	Error of +50%
1) BOC unit cost curve	86.5%	91%	82.6%
Diff		+4.5	-3.9
2) UK Industry data	81.03%	86.5%	76.3%
Diff		+5.47	-4.75
3) France EEC NIMEXE Exports	78.0%	85.9%	71.0%
Diff		+7.9	-7.0
4) Germany Electric Welding M/cs 1962-69	137.4%	121.3%	155.4
Diff		-16.1	+18.0
5) Germany Rectifiers 1970-77	26.5%	46.5%	15.2%
Diff		+20.0	-11.3
6) Japan DC Arc Welders 1965-76	73.7%	80.5%	68.2%
Diff		+6.8	-5.5
7) Netherlands EEC NIMEXE imports 1966-71	71.6%	80.8%	63.8%
		+9.2	-7.8
8) Netherlands EEC NIMEXE exports 1966-71	161.5%	131.7%	198.0%
		-29.8	+36.5
Average difference		12.5%	11.8%

Table 39 Analysis of those sets of data which cover a long period of time

1. Japan – Sales of arc welding machines

	1948–55	1955–65	1965–67	1967–70
Type of growth	Steady growth low volumes	Steady growth oscillating vols.	Volume doubles	Growth continues steadily
Growth in units p.a.	1300 – 7000	7000 – 62,000	62,000 – 136,000	136,000 – 201,000
Ave. comp. growth rate	20.1%	26.3%	50.4% p.a.	14.3% p.a.
Price behaviour (Price in £'000)	Increases 66 to 140	Declines steadily 140 to 60	Increases sharply 60 to 132	Falls, then increases sharply 132 to 105
Experience curve slope	139%	81% (i.e. only time exp. curve, in accepted sense, fits the data)	436%	128%

2. U.S.A. – Data on value of industry shipments and cost of materials per dollar of shipments

	1958–63	1963–66	1966–72
Type of growth	Steady growth	High growth	Decline except for 1972
Growth in const. value of shipments m$	453.7 to 598.2	598.2 to 928.3	928.3 to 757
Ave. comp. growth rate	4.2%	15.7%	Decl. .42% p.a.
Unit cost behaviour	Increase 1958–62 Then fall in 1963	Steady increase	Decline
Cost of materials per dollar of shipments	.55 to .51	.51 to .53	.53 to .48
Experience curve slope	93%	111%	91%

Table 39 Continued — Analysis of those sets of data which cover a long period of time

3. Bulbs - Unit Price

	1956-65	1965-72	1972-77
Type of growth	Steady	High	Plateau
Ave. comp. growth rate	9.8%	11.4%	Decline 1.2%
Price behaviour	Steady decline	Steady decline	Slight increase
Experience curve slope	43.7%	93.3%	106.9%

4. Syphons - Unit Price

	1956-62	1962-66	1966-73	1973-77
Type of growth	Steady	High	Plateau	Decline
Ave. comp. growth rate	8.3% p.a.	40.5% p.a.	2.4% p.a.	Decl. 4.8% p.a.
Price behaviour	Overall slight decline	Decline	Steady decline	Decline except for 1977
Experience curve slope	100.5%	84.9%	79.2%	78.9%

5. Passenger Cars - Unit Price

	1954-68	1968-73	1973-77
Type of growth	High	Plateau	Decline
Ave. comp. growth rate	7.1% p.a.	Decline .72% p.a.	Decline 40.3% p.a.
Price behaviour	Steady then decline	Increase	Increases fairly steadily
Experience curve slope	86.7%	182.6%	174.8%

Appendix E

Analyses to investigate the causes of lack of cost reduction

Index

5. <u>Investigation of any correlation between unit cost of the product and rate of output</u>

5.1 Data

5.2 Analyses

5.3 Results

5.4 Conclusions

6. <u>Width of range of models in production</u>

6.1 Data

6.2 Analyses

6.3 Results

6.4 Conclusions

7. <u>Investigation of changes in the product mix over the period 1965/66 to 1976/77</u>

7.1 Data, sources and adjustments

7.2 Analyses

7.3 Results

7.4 Conclusions

8. <u>Investigation of any increase in complexity of the product over the period 1965/66 to 1976/77</u>

8.1 Data and adjustments

8.2 Analysis

8.3 Results

8.4 Conclusions

Appendix E - List of Tables

E.8.2 Raw data - TIG.

E.8.3 Annual number of complexity units produced, and average number of complexity units per rectifier.

Appendix E. Analyses to investigate the causes of the lack of cost reduction

1. Component parts of the cost of production

1.1. Data and adjustments

Source The cost data is taken from the annual profit and loss accounts produced by the factory, from 1964/66 to 1976/77 with the omission of 1973/74 for which the documents could not be found.

Data (See Table 1.1 and 1.2)

Data was available for a) direct costs, divided into materials purchased, and direct wages and pensions; b) fixed costs, divided into six main categories, each further sub-divided into individual costs.

Adjustments

a) Stock levels were used to adjust materials purchased to find estimates of materials consumed. It was thought to be more representative of actual materials consumed if the stock level and purchase figures were deflated before the adjustment, so that all are at constant value when the adjustment is made. (See Appendix C, Table 4.3 for figures.)

b) Data is deflated using the Index of Wholesale prices of Home sales of all manufactured products. (See Table 1.3.)

c) Total annual cost in the various categories, having been deflated, is divided by annual volume of production to give cost per unit. (See Table 1.4.)

1.2. Methods used in analysis

The main methods used are as follows:

a) Finding the proportions formed by the major elements of the factory costs. (See Tables 1.1 and 1.5.)

b) Using linear regression analysis to test the statistical significance of any apparent trends over the period 1966-77, both in annual deflated value of various types of cost per unit of production, and in the proportion of the total formed by these costs.

In each case the model is of the form

$$y = a + bx, \text{ where } x \text{ represents elapsed time,}$$
$$1966\ x = 1, \ldots\ldots\ldots 1977\ x = 12$$

and is tested using the techniques of linear regression described in Chapter Four. (See main report, 4.3.1.)

Estimated parameters of the model, values of the descriptive statistic C (describing goodness of fit) and the test statistic F are given in Table 1.6. The level of significance for the relationship derived from the value of F is given in brackets underneath.

c) Values for 1966 and 1977 are calculated from the model in each case, and used to estimate the average compound growth rate over the period. These are also given in Table 1.6.

Table 1.1

Raw data on direct and fixed costs at the factory

	Total costs per annum (£'000)										
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Direct costs												
Material consumed	321	242	353	550	655	558	512	753		1361	1430	2199
Direct wages and pensions	45	50	83	135	137	121	120	140		255	323	484
TOTAL	366	292	436	685	792	679	632	893		1616	1753	2683
Fixed costs												
Administration	25	31	35	45	66	84	87	111		215	271	410
Establishment	8	9	14	19	23	24	24	31		48	62	103
Financial	5	5	6	6	3	3	1	1		2	-	1
Professional	-	1	1	2	14	3	2	-		7	-	17
Other	4	1	2	5	3	4	3	11		4	5	13
Carriage	3	4	6	10	9	8	9	8		20	18	23
Total Fixed	45	51	64	87	118	126	126	162		296	356	567

cont./

Table 1.1 continued

Raw data on direct and fixed costs at the factory

Proportion of direct to fixed costs

Direct	.89	.85	.87	.89	.87	.84	.83	.85	.84	.83	.83
Fixed	.11	.15	.13	.11	.13	.16	.17	.15	.16	.17	.17

Proportion of materials to labour in direct costs

Materials	.88	.81	.82	.81	.85	.82	.81	.82	.84	.83	.82
Labour	.12	.19	.18	.19	.15	.18	.19	.18	.16	.17	.18

Table 1.2

Raw data on breakdown of fixed costs at the factory

	Total cost per annum(£'000)											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Administration												
Salaries	20.2	25.2	27.6	35.8	54.0	71.2	74.8	82.7		123.4	160.5	236.9
Staff Pensions	0.9	1.1	1.8	2.6	3.0	4.3	4.9	13.3		67.0	76.2	120.5
Employee services	-	-	-	-	-	-	-	5.2		5.7	7.9	23.6
Telephone & telex	1.4	1.4	2.2	3.2	4.0	3.6	3.4	4.9		6.1	10.0	12.6
Printing and stationery	1.5	1.7	1.5	1.9	2.7	2.7	2.1	2.1		3.5	6.9	7.1
Postage	0.3	0.3	0.5	0.8	0.9	0.9	1.1	1.2		1.7	2.3	3.0
Equipment rentals	0.7	0.8	0.8	0.9	0.9	0.6	0.8	0.8		7.2	6.1	4.8
Office maintenance	-	0.1	0.3	0.2	0.1	0.2	0.2	0.5		0.8	1.0	1.9
TOTAL ADMIN.	25.0	30.6	34.7	45.4	65.6	83.5	87.3	110.7		215.4	270.9	410.4
Establishment												
Rates	2.0	2.5	3.7	4.9	6.1	8.0	8.9	11.2		13.6	20.3	25.1

cont./

Table 1.2 cont.

Raw data on breakdown of fixed costs at the factory

Establishment cont.	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Fuel, light, power	2.3	2.5	3.3	3.9	4.3	4.4	4.5	6.1		14.8	17.7	28.2
Building maintenance	0.9	0.7	1.5	1.2	1.6	1.4	1.2	1.3		7.5	9.0	16.7
Plant maintenance		0.5	0.9	2.0	2.1	1.8	1.9	3.1				
Loose tools	0.8	0.8	1.3	3.5	2.7	1.3	1.0	1.5		-	-	-
Cleaning/laundry	0.7	0.8	0.9	0.9	1.2	1.4	1.4	1.9		-	3.0	4.3
Side services	-	-	-	-	-	-	-	-		3.3	1.3	13.1
Security	-	-	-	-	-	0.6	0.7	2.2		2.4	3.5	4.5
Insurance	1.6	1.3	2.3	2.5	5.1	5.0	3.7	3.5		6.1	7.2	11.3
TOTAL ESTABLISHMENT	8.3	9.1	13.9	18.9	23.1	23.9	23.3	30.8		47.7	62.0	103.2
Financial												
Loan interest	2.8	3.5	5.2	4.3	1.4	1.8	-	-		-	-	-
Cancel penalties	-	-	-	-	-	-	-	-		0.1	-	Neg.
Discounts	1.1	1.2	1.4	1.2	1.6	1.2	1.0	0.8		1.6	-	0.5

cont./

Table 1.2 cont.

Raw data on breakdown of fixed costs at the factory

Financial cont.	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Commission	1.4	-	-	-	-	-	-	-		0.5	-	-
Bank charges	Negligible throughout											
TOTAL FINANCIAL	5.3	4.7	6.6	5.5	3.0	3.0	1.0	0.8		2.2	-	0.5
Professional												
Audit & accounts	0.4	0.3	0.4	0.6	0.9	0.9	0.8	(0.4)		-	-	-
Computer services	-	-	-	-	-	-	0.9	0.1		6.7	-	14.3
Patent fees	-	1.1	0.2	0.3	1.3	0.8	0.5	-		-	-	-
Business consult. fees	-	-	-	-	11.5	1.6	-	-		-	-	-
Legal & Professional	-	neg.	-	1.1	-	0.1	0.1	-		0.5	-	2.5
TOTAL PROFESSIONAL	0.4	1.4	0.6	2.0	13.7	3.4	2.3	(0.3)		7.2	-	16.8
Other Expenses												
Motor expenses	0.2	0.4	0.5	0.5	0.4	0.7	0.6	0.8		1.5	1.5	3.3

cont./

Table 1.2 cont.

Raw data on breakdown of fixed costs at the factory

Other expenses cont.	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Entertainment	-	-	-	-	-	-	-	0.6		0.7	1.2	3.0
Travel & business expenses	0.6	0.6	0.7	0.8	0.9	1.0	1.3	1.2		1.2	2.2	5.9
Adverts and exhibitions	-	-	-	2.3	0.7	0.5	0.2	-		0.1	-	-
Trade papers/subs.	0.1	0.1	0.2	0.3	0.2	0.3	0.3	0.2		0.2	0.3	0.3
R & D	2.2	-	-	0.4	-	-	-	8.1		-	-	-
Sundry	0.4	0.4	0.9	1.2	1.2	1.1	0.9	-		-	0.1	0.1
TOTAL OTHER	3.5	1.5	2.3	5.5	3.4	3.6	3.3	10.9		3.7	5.3	12.6

Table 1.3

Direct and fixed costs at the factory, deflated

	Total annual costs, deflated (£'000)											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Index (See 1.1(b))	85.6	86.5	89.9	93.4	100	109	114.8	123.2	152.0	188.7	218.6	258.3
Direct costs												
Materials	377	266	396	594	668	528	451	621		721	723	938
Direct wages and pensions	53	57	92	144	137	111	105	114		135	148	188
TOTAL	430	323	488	738	805	639	556	735		856	871	1126
Fixed costs												
Administration	29	36	39	48	66	77	76	90		114	124	159
Establishment	9	10	16	20	23	22	21	25		25	28	40
Financial/ Professional	6	7	8	9	17	6	3	1		5	-	5
Other	5	1	2	5	3	4	3	9		2	2	5
Carriage	4	5	6	11	9	7	7	6		11	9	10
TOTAL	53	59	71	93	118	116	110	131		157	163	219

cont./

Table 1.3 cont.

Direct and fixed costs at the factory, deflated

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Total Direct and Fixed	483	382	559	831	923	755	666	866		1013	1034	1345

Table 1.4

Direct and fixed cost per unit at the factory (deflated)

	Cost per unit, deflated £											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Volume of production	2538	2378	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461
Direct cost												
Materials	148	112	126	163	182	158	141	170		174	183	210
Labour	21	24	29	39	37	34	33	31		33	37	42
Total direct	169	136	155	202	219	192	174	201		207	220	252
Fixed costs												
Administration	11	15	12	13	18	23	24	25		28	31	36
Establishment	4	4	5	6	6	7	7	7		6	7	9
Financial/ professional	2	3	3	2	5	2	1	Neg.		1	-	1
Other	2	Neg.	1	1	1	1	1	2		1	1	1
Carriage	2	2	2	3	2	2	2	2		2	2	2
Total fixed	21	24	23	25	32	35	35	36		38	41	49
Fixed and direct	190	160	178	227	251	227	209	237		245	261	301

Table 1.5

Proportions formed by major items of fixed costs at the factory

	Proportion of total fixed costs											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Administration												
Salaries & staff pensions	.47	.52	.46	.44	.48	.60	.63	.59		.64	.67	.63
Employee services	-	-	-	-	-	-	-	.03		.02	.02	.04
Phone, printing, postage etc.	.07	.07	.07	.07	.07	.06	.05	.05		.04	.05	.04
Equipment rentals & maintenance	.02	.02	.02	.01	.01	.01	.01	.01		.03	.02	.01
TOTAL ADMIN	.56	.61	.55	.52	.56	.67	.69	.68		.73	.76	.72
Establishment												
Rates, fuel, light, power	.10	.10	.11	.10	.09	.10	.11	.11		.10	.11	.09
Plant & building maintenance, tools	.04	.04	.06	.08	.06	.03	.03	.04		.02	.03	.03
Site services	-	.01	.01	.01	.01	.02	.02	.02		.02	.02	.04
Insurance	.04	.02	.04	.03	.04	.04	.03	.02		.02	.02	.02
TOTAL ESTABLISHMENT	.18	.17	.22	.22	.20	.19	.19	.19		.16	.18	.18
TOTAL FINANCIAL	.11	.10	.09	.07	.02	.02	.01	.01		.01	-	Neg.

cont.

Table 1.5 cont.

Proportions formed by major items of fixed costs at the factory

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Professional												
Audit & accounts	.01	.01	.01	.01	.01	.01	.01	-		-	-	-
Computer services	-	-	-	-	-	-	.01	-		.02	-	.02
Other	-	.01	.01	.01	.11	.01	-	-		-	-	.01
TOTAL PROFESSIONAL	-	.02	.02	.02	.12	.02	.02	-		.02	-	.03
Other expenses												
Motor, travel, ents.	.02	.01	.02	.01	.01	.01	.01	.02		.01	.01	.02
R & D	.05	-	-	-	-	-	-	.05		-	-	-
Other	.02	.01	.01	.04	.01	.02	.01	-		-	-	.01
TOTAL OTHER	.09	.02	.03	.05	.02	.03	.02	.07		.01	.01	.03
Carriage	.06	.08	.09	.12	.08	.06	.07	.05		.07	.05	.04

TABLE E 1.6.

Proportions formed by major items of costs at the factory.

	Proportion of total costs											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Materials	.78	.71	.71	.71	.72	.69	.68	.71		.71	.68	.68
Labour	.11	.15	.17	.17	.15	.15	.16	.13		.13	.15	.15
Salaries, staff pensions Employee services	.05	.08	.06	.05	.06	.09	.10	.10		.10	.12	.12
Remainder of admin.	.01	.01	.01	.01	.01	.01	.01	.01		.01	.01	.01
Rates, fuel, light, power	.01	.01	.01	.01	.01	.02	.02	.02		.01	.02	.01
Establishment maintenance, services, & insurance	.01	.01	.01	.02	.01	.01	.01	.01		.01	.01	.01
Financial/ Professional	.01	.01	.01	.01	.02	.01	.005	-		.01	-	.01
R & D	.01	-	-	-	-	-	-	.01		-	-	-
Carriage	.01	.01	.01	.01	.01	.01	.01	.01		.01	.01	.01
Other	-	.01	.01	.01	.01	.01	.005	-		.01	-	-

TABLE E 1.7.

Results from linear regression analysis and estimated average compound growth rates of unit costs at the factory

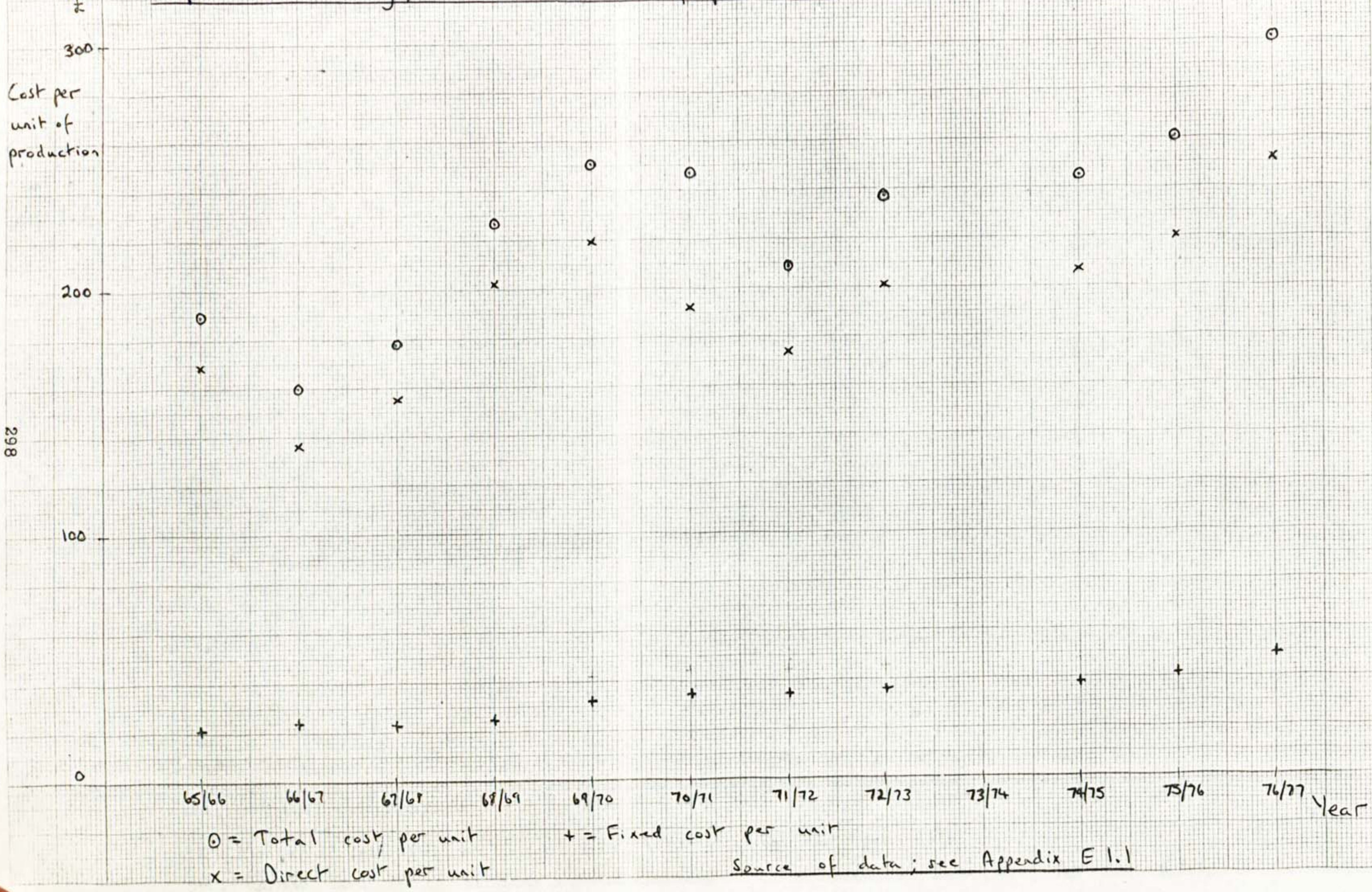
Set of data	Regression line	C	F (Sig level)	A.c.g.rate % p.a.
Material cost/unit	y=123.96+5.846x	.77	13.4 (99%)	3.725
Labour cost/unit	y=25.227+1.196x	.70	8.8 (97.5%)	3.741
Total direct cost/ unit	y=149.092+7.101x	.79	15.1 (99%)	3.755
Administration cost/unit	y=7.963+2.146x	.97	150.0 (99.9%)	11.573
Establishment cost/ unit	y=4.010+0.334x	.89	34.6 (99.9%)	5.735
Financial/profess[1] cost/unit	y=3.405-0.253x	NOT SIG.		Decline
'Other' cost/unit	) Clearly no trend			
Carriage cost/unit	)			
Total fixed cost/ unit	y=21.040+1.515x	.90	37.0 (99.9%)	5.159
Total fixed+ direct cost/unit	y=170.131+8.6172	.84	20.9 (99%)	3.943

TABLE E 1.7. (Cont.)

Analysis of proportions formed by various costs

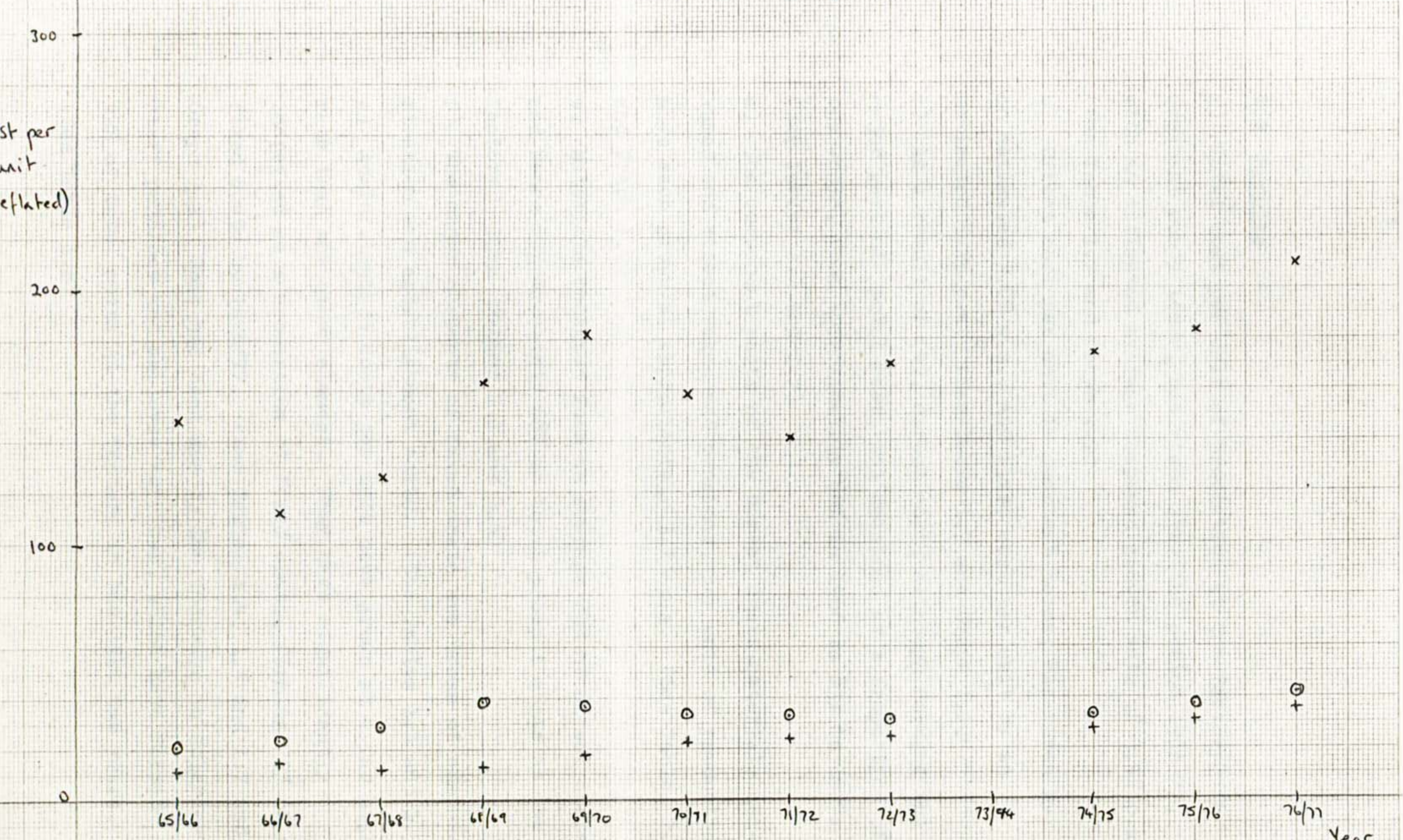
Direct/total cost	y=0.884-0.00475x	.67	8.1 (97.5%)	-
Admin./total fixed cost	y=0.518-0.197x	.86	26.6 (99.9%)	-
Material /total factory cost	y=0.740-0.00523x	.68	7.79 (97.5%)	-
Labour/total factory cost	y=0.147-0.0000133x	.03	0.008 NOT.SIG	-
Salaries, staff pensions, employee services/total factory cost	y=0.0451+0.00629x	.89	32.7 (99.9%)	-

Graph E.1 Factory; Total unit costs of production over the period 1965/66 to 1976/77



Source of data; see Appendix E 1.1

Graph E.2 Major elements of costs at the factory 1965/66 to 1976/77



X = Materials cost per unit + = Administration cost per unit

⊙ = Labour cost per unit

Source of data see Appendix E1.1

1.3 Results

a) Total cost per unit of production at the factory, in constant money terms, has risen over the period 1966-77, with an estimated average compound growth rate of 3.9% p.a. (See Table 1.7 and Graph 1.1)

b) Direct cost per unit in constant terms, has risen by an estimated 3.8% p.a., and fixed cost per unit by an estimated 5.2% p.a. (See Table 1.7 and Graph 1.1)

c) As a result of (b), direct cost, although forming the major part of total cost, has declined as a proportion of the whole, from approximately 89% in 1966 to 83% in 1977. (See Tables 1.1 and 1.7)

d) The component parts of the direct costs,materials consumed and direct wages and pensions, per unit of production, have each grown at approximately 3.7% p.a. (See Table 1.7 and Graph 1.2)

e) Materials consumed form an average 83% of direct costs, and hence approximately 68% of total product costs at the factory. (See Tables 1.1 and 1.6)

f) The major elements of fixed costs are those of administration and establishment costs. (See Tables 1.1 and 1.5)

g) Administration costs per unit have grown at a far higher rate than any other element. They have significantly increased as a proportion of fixed costs, forming 72% of all fixed costs by 1976/77. (See Tables 1.4, 1.5 and 1.7 and Graph 1.2) This has been due to the increase in salaries, staff pensions and employee services, which have formed 12% of total costs at the factory in the last two years. (See Table 1.6)

1.4 Conclusions

Whilst all the elements of factory cost per unit of production have increased over the period 1966-77, the element formed by fixed cost has increased at a faster rate.

This is mainly due to the increase in overhead costs of the administrative staff.

However, as the major elements of the cost of production are still the direct costs of material and labour, and these costs per unit have increased over the period in question, they require further investigation.

Appendix E.2.

Investigation of increase in fixed assets at the factory

The purpose of this enquiry is to discover whether the rise in overhead costs has been due, partly or wholly, to any expansion of premises, plant and machinery or other fixed assets which give rise to overhead costs.

2.1 Data (See Table 2.1)

The only available data is on the book value of fixed assets, according to the annual account, i.e., as they appear on the balance sheet.

Although the net book value includes depreciation, some indication of the expansion of premises and plant is given by the increase in net book value, plus the amounts spent on additions in each year.

2.2 Analysis

Data is deflated using the usual index (Index of Wholesale prices of Home Sales of all manufactured goods), and the average compound growth rate is calculated for the annual deflated value of total fixed assets for the period 1965/66 to 1976/77.

2.3 Results

Linear regression analysis of deflated annual value of all fixed assets gives $y = 72.099 + 33.404x$, a.c.g. rate 1965/66 to 1976/77 = 14.613.

Since BOC took over HWR, in 1972, addition of fixed assets was spasmodic, with a general depreciation of values in 1974/75 and 75/76, followed by a large amount of spending in 1976/77, with figures for WIP on property, plant and fixtures and fittings relating to the start of the new factory.

Hence, the average compound growth rate for increase in fixed assets, in constant value terms, for the period 1965/66 to 1973/74 was found to be 13.1% p.a.

2.4 Conclusions

Apart from the work started on the new factory in 1976/77, there have been constant additions and improvements to the old premises and its plant. This has resulted in a growth in the value of the fixed assets of 13-14% p.a., whereas the growth in volume of output has only been 4.9% p.a.

Table 2.1

Fixed assets at the factory (from annual accounts)

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	76/76	76/77
						Actual £'000						
Freehold Property Net	80	101	135	173	219	216	289	341		334	430	1713*
(Additions)	(6)	(23)	(37)	(14)	(52)	(2)	(80)	(33)			(101)	(1287)
Plant & machinery Net	17	18	26	38	40	38	35	81		76	81	342
(Additions)	(4)	(4)	(11)	(7)	(6)	(4)	(2)	(19)				(275)+
Loose Tools	1	-	-	-	-	-	-	-		-	-	-
Furniture, F & F net	3	4	5	6	9	8	8	28		18	22	32*
(Additions)	-	(1)	(2)	(-)	(3)	(1)	(2)	(1)				(15)
Motor Vehicles	1	1	2	1	1	1	2	4		3	4	7
(Additions)		(1)	(-)	-	(1)	-	(1)	(2)				(3)
Depreciation return								-82				
Office Equipment	3	4	4	5	5	5	5	-		-	-	-
TOTAL	105	128	172	223	274	268	338	372		431	537	2094

cont./

Table 2.1 cont.

Fixed assets at the factory (from annual accounts)

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
						Deflated						
Freehold Property Net	93	117	150	185	219	198	252	277		177	197	663
Plant & machinery Net	20	21	29	41	40	35	30	65		40	37	133
Tools, Furniture, F & F Net	5	5	6	6	9	7	7	23		9	10	12
Motor Vehicles	1	1	2	2	1	1	2	3		2	2	3
Depreciation								-66				
Office Equipment	4	4	4	5	5	5	5	3				
TOTAL	123	148	191	239	274	246	294	302		228	246	811

* All contain sums for WIP - on new buildings, plant, canteen facilities, etc.

3. Investigation of the basic costs of materials and labour

The constituent materials required in the manufacture of rectifiers are, with approximate proportions, as follows:

Copper	38%
Laminations	32%
Metals, electrical parts, consumables	30%

The investigation seeks to find out whether the basic costs of these materials, and of labour, has increased at a higher rate than that of the index used to deflate the costs.

3.1. Data and adjustments

3.1.1. Materials

The average annual prices of copper for each calender year 1968-77 were obtained from the London Metal Exchange. Amounts for 1968/69 and previous years are in £'s per long ton, subsequent years in £'s per metric ton.

This is compared with the standards for the cost of copper used by BOC AE in their standard costing from 1973/74 to 1976/77, in £'s per kg.

Standards have also been obtained for the costs of laminations and steel sheet. These are set in June for use in the following financial year, commencing in September.

All have been deflated using the Index of Wholesale prices of Home Sales of all manufactured products. (See Table 1.3, this Appendix.)

3.1.2. Labour rates

Source of information - annual profit and loss account and reports, plus standard labour rate used by accounts department for direct costing (available for 1973/74 onwards).

The labour rate in £ per hour is known or calculated as follows:

1973/74 - 1976/77: known from direct costing

1968/69 - 1972/73: standard labour rate for 1973/74 to 1976/77 is used in conjunction with known number of workers and wages bill to calculate number of working hours per year.

$$\frac{\text{Total wages bill}}{\text{Number of workers x standard hourly rate}} = 1315 \text{ hours}$$

For most years the number of people earning direct labour wages is obtainable from annual reports, or can be estimated from the following year's report if an increase or decrease is recorded.

Total wages bill is known. Hence, the average hourly rate can be calculated from

$$\frac{\text{Total wages bill}}{\text{Number of workers x 1315}} = \text{£ per hour}$$

The labour rate per hour is then deflated using the same index of inflation (See 3.1.1).

Also given is the output per worker

$$- \frac{\text{Annual revenue of sales from HWR (deflated)}}{\text{Number of workers}}$$

3.2. Analyses

Deflated data for cost of materials and labour is tested by linear regression techniques for the significance of any trend over the periods for which data is available.

Model: $y = a + bx$, where x represents elapsed time

1966, x = 1 ..... 1977, x = 12

using techniques of linear regression as described in 4.3.1. of main report.

3.3. Results

a) Regression analysis on copper prices 1968-77 gives

$y = 649.40 - 32.545x$

C = .71, F = 8.05 sig. at 5%

average compound rate of decline over the period 1968-77 is 7.4% p.a. (see Graph 3.1).

b) Regression analysis on BOC copper standards does not give a statistically significant trend as there are only 4 years of data. However, the standard cost for copper has declined over the period 1973/74 to 1976/77 by an average 6.5% p.a.

c) Regression analysis similarly gives no significant results for both laminations and steel sheet, due to the short run of data.
Both standards do rise over the period 1973/74 to 1976/77, laminations by an average of 1% p.a. and steel sheet by 8% p.a. c.g. rate.

d) Regression analysis of deflated average labour rate per hour for 1968/69 to 1976/77 also shows no significant trend (C = 0.33, F = 0.85). The hourly rate rises to a peak in 1970/71, then declines, and then rises again in 1975/76. The policy of the factory management was not to decrease the number of operators when output volumes were low, but to engage them in other tasks. Hence, in this context, labour costs were more of a fixed cost. (Graph 3.1)

Since 1971/72 the number of operators has increased but revenue (deflated) per worker appeared to have fallen steadily. However, when tested by linear regression, the trend was not found to be statistically significant (C = -0.29, F = 0.63, not sig. at 5%).

3.4. Conclusions

The rather limited evidence suggests that even if the absolute cost of laminations and steel sheet has increased, this will be balanced by the relative decline in the price of copper. Thus, there is no evidence that the absolute cost of raw materials has increased at a higher rate than the index of inflation.

The absolute cost of labour, in terms of labour rate per hour has also remained fairly constant.

Table 3.1

Data on cost of raw materials and labour

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Copper prices from LME												
L's per long tonne			524	621								
Equiv. per metric ton			516	611								
£'s per metric ton					588	444	428	727	877	557	782	750
Deflated			574	654	588	407	371	591	577	295	357	290
(For Index see Table 1.3)												
Standard costs from HWR, £ per kg												
Copper - actual									1.42	1.35	1.64	1.96
- deflated									.936	.715	.750	.759
Laminations - actual									10.38	12.52	14.84	18.15
- deflated									6.83	6.63	6.79	7.03
Steel sheet - actual									.117	.161	.220	.250
- deflated									.077	.085	.101	.097

cont./

Table 3.1 cont.

Data on cost of raw materials and labour

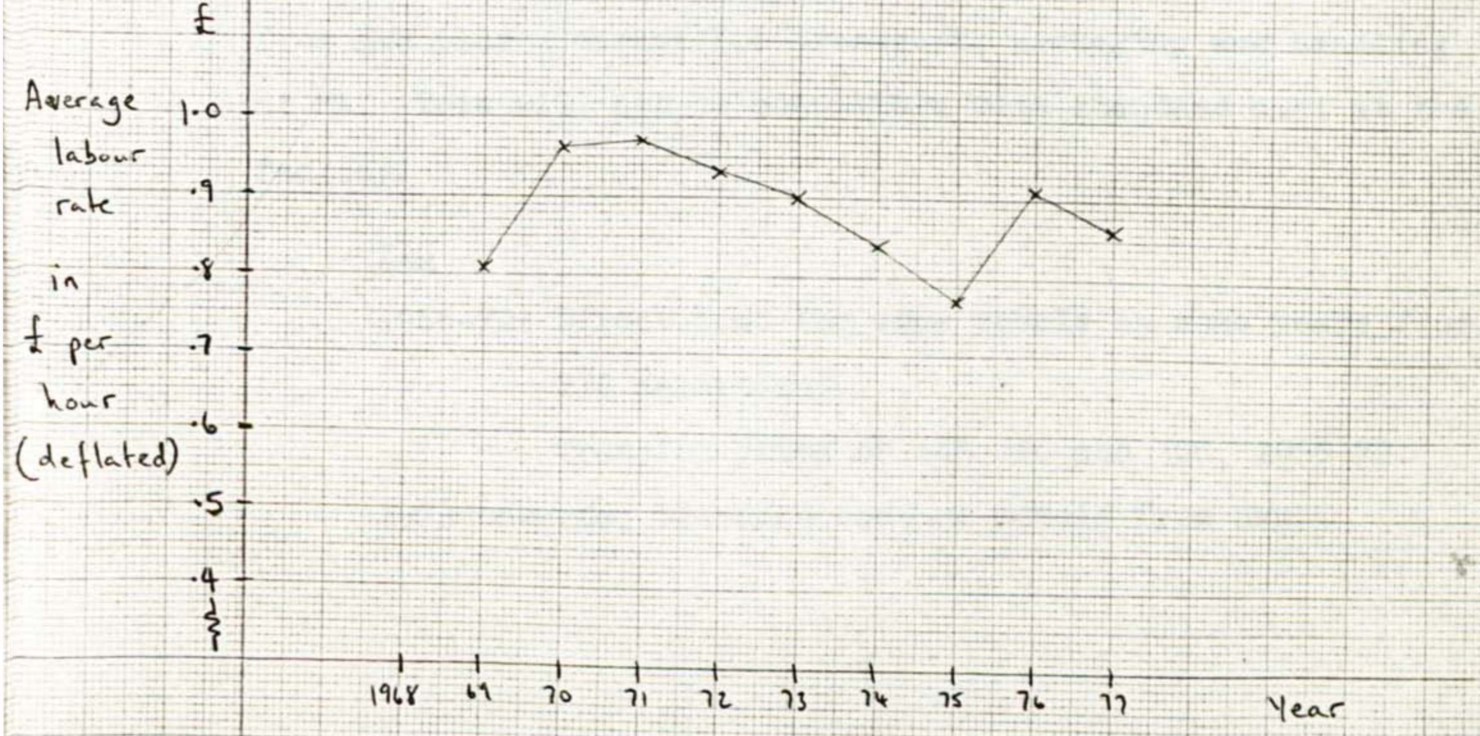
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Labour costs from HWR												
Average labour rate in £/hr				.77*	.96*	1.053*	1.07*	1.11*	1.28	1.45	2.00	2.22
- Deflated				.82	.96	.97	.93	.90	.84	.77	.91	.86
Number of workers				134	108*	87	85*	109	12o*	133*	131	166
Output/worker £'000, deflated				16	22.5	25	26	26	23	19	18.5	16.5

* - calculated or estimated

Graph E.3 Costs of raw materials and labour 1968-77

a) Copper prices from the London Metal Exchange

b) Labour rate per hour



Source of data see Appendix E.3.1

4. <u>Investigation of the effect of design changes on unit costs of MIG and TIG rectifiers</u>

The main problem was the sparcity of any historical data on direct costs of individual models. However, the data which was available enabled some comparison of the cost of manufacturing each model to be made, although not facilitating any analysis of trends in unit cost of individual models over any period of time, since data pre and post 1973 was not consistent.

4.1. <u>Data</u> (See Tables 4.1 and 4.2)

<u>Source</u> - <u>MIG</u>

1966 - 72; Direct cost for some models, some years, held by TIG department

1973 onwards; Standard costs of each model as prepared by costing department of HWR.

Note: Direct cost refers to that sustained by BOC, and probably includes the transfer price of the rectifier bought from HWR plus a markup for transport, packaging and handling at MK. This will not be compatible with standard cost at the factory.

<u>TIG</u>

1966-72; Direct cost for some models in some years from TIG department.

Transfer price of ADR 200 and 300, 1966-72.

1973 onwards; Standard cost of models from HWR.

Table 4.1

MIG - Unit cost and production volumes of individual models

(All costs deflated)

Direct or standard cost (deflated) £, plus nos. produced

		65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MRCS 200B	Cost		160	167	160	177							
	Nos.	1200	1200	1000	750	669	114						
SMR 200	Cost								64	65	65	67	71
	Nos.					176	589	502	752	861	410	290	392
SMR 225	Cost								71	74	73		77
	Nos.						246	112	157	169	84	20	-
TM 225	Cost												77
	Nos.											-	345
SMR 250	Cost									85	85		
	Nos.								41	53	18		
SMR 300	Cost								146				
	Nos.						152	126	267	387	73		
SMR 350	Cost									160	148	168	173
	Nos.						1	149	206	269	546	333	139
TM 350	Cost											149	151
	Nos.											247	776

cont./

Table 4.1 cont.

MIG - Unit cost and production volumes of individual models

Direct or standard cost (deflated) £, plus nos. produced

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
SMR 400 Cost					444			217	292			
Nos.	25	305	331	544	574	223	103	92	95	80	-	-
SMR 500 Cost												247
Nos.						54	197	124	238	273	274	363
TM 600 Cost												267
Nos.											-	2
STR 650 Cost					334	360						
Nos.	-	67	117	222	230	77	49	42	125	128	117	64
SPR Cost		387	391	418	469	505						194
(and TMSPR) Nos.	60	70	140	171	169	137	56	81	75	42	50	48
Autolynx Cost					205							133
Nos.	-	-	-	352	690	796	890	791	819	721	847	700
Lynxpak 210 Cost												133
Nos.										91	276	239

Table 4.2

TIG - Unit cost and production volumes of individual models

(All costs deflated)

Direct or standard cost in £ (deflated) plus nos. produced

		65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
AMR 150	Cost					310	317						
	Nos.	114	150	150	54	64	28	102	8	56	2	-	-
AMR 250	Cost					370	372			227	230	237	
	Nos.	60	60	67	33	10	15	37	13	30	49	20	
AMR 400	Cost					469	471			264			
	Nos.	30	30	30	31	14	10	13	32	49	8	-	-
TT DC 250	Cost											274	296
	Nos.										-	47	79
ADR 200	Cost	249	250	244	243	224	212	213	186				
	Nos.	30	32	60	89	61	115	108	84	53			
ADR 300	Cost					292	283		207	200	196	215	218
	Nos.	50	50	202	194	212	205	253	285	408	487	184	94
TA AC/DC 375	Cost												261
	Nos.										-	217	302
MNR 300	Cost									142			
	Nos.	26	26	71	112	84	99	36	32	123	21	-	-
MNR 400	Cost									160	151	152	
	Nos.	154	159	303	293	238	118	124	186	146	454	195	18

cont/.

Table 4.2 cont.

TIG - Unit cost and production volumes of individual models
(All costs deflated)

		65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	76/76	76/77
		Direct or standard cost in £ (deflated) plus nos. produced											
TA DC 525	Cost											160	161
	Nos.										-	112	193
MNR 650	Cost								195	192	193	202	212
	Nos.	75	94	85	65	103	50	20	52	106	126	153	35
TA DC 825	Cost											218	223
	Nos.										-	55	45
TDC 150	Cost									80	84	87	92
												TA	TA
	Nos.							35	60	150	107	46	140
DAC 240	Cost									107			
	Nos.					-	60	30	38	30	-		
DAC 320	Cost									157	143	141	
	Nos.	-	-	21	96	62	46	7	5	79	65	1	-
TA AC/DC 320	Cost											146	157
	Nos.									-	-	66	89
TT AC 350	Cost									-	-	181	223
	Nos.											42	40
TAR 300 (& TT)	Cost									38	36	38	
	Nos.							-	30	84	64	96	120

4.2. Analysis

Since data for costs is inconsistent over periods of time, particularly pre and post 1972/73, the analysis consists of classifying products into categories of cost, and comparing costs of models with their replacements.

MIG

Most expensive: SPR, STR 650, SMR 400, 500 and TM 600

Fairly expensive: SMR 300, 350 and TM 350 (though TM 350 slightly cheaper than SMR 350)

Medium price: MRCS 200 B, Autolynx and Lynxpak 200, SMR 250

Lower range of price: SMR 200, 225, TM 225

TIG

Most expensive: AMR 250 and 400, TA AC/DC 375, TT DC 250 (most expensive of all)

Fairly expensive: AMR 150, ADR 200 and 300, MNR 650, TT AC 350, TA DC 825

Medium price: MNR 300 and 400, TA DC 525, TA AC/DC 320, DAC 320

Low price: DAC 240, TDC 150, TAR 300 (plus TA TDC 150 and TT TAR 300)

4.3. Results

MIG - In the early years 1965/66 to 1967/68 production is confined to four basic models, one fairly low price and the others at the heavy, costly end of the range.

This is followed by the introduction of the Autolynx in 1968/69, followed by an extension of the range with the introduction of the SMR 200, 225, 300, 350 and 500.

The new SMR models replace the MRCS 200 B and, later the SMR 400.

Thus, although the MRCS 200 B is replaced by a cheaper model, the SMR 200, this replacement coincides with the introduction of more expensive models.

Later, in 1975/76 and 1976/77 comes the rationalisation of the range with the replacement of the SMR range by the TM 225, 350 and 600. The TM 225 is the same cost as the SMR 225, TM 350 slightly cheaper than the SMR 350, and the TM 600 slightly more expensive than the SMR 500.

TIG - Production at the beginning of the period in question is of a fairly wide range consisting of the expensive AMR range, fairly expensive ADR range and slightly cheaper MNR range of models. These continue unchanged until the rationalisation of the range in 1975/76 and 1976/77.

However in the interim period there is introduction of more models at the lower end of the market, the TDC 150, TAR 300 and DAC 240, with the rather more expensive DAC 320.

When the range is rationalised, each of the AMR and ADR ranges are replaced by a single model, but of higher specification. Thus, each is replaced by more costly models.

The MNR range is replaced by two models, the TA DC 525 and 825, both slightly more costly.

The DAC 240 and 320 disappear, to be replaced by the more expensive TA AC/DC 320.

4.4. Conclusions

Until 1975/76, design effort in MIG was put into extending the range, although some newer models were produced more cheaply than those they replaced.

When the range was rationalised, and design became more cost-oriented, efforts were made to design models which could be produced at lower direct cost. This succeeded in the middle of the range, but not at the heavier end where direct cost of products increased.

Throughout, production continued of several older type and very costly models, presumably to fulfill customer demand.

The main bulk of the TIG range however remained unchanged until 1975/76, with the addition of a few models in the lower cost and amp range of the market. But with the rationalisation of the range, TIG products in general became more highly specified and thus more costly.

5. Investigation of any correlation between unit cost of product and rate of output

The analyses test for statistically significant correlations between the average unit cost of a rectifier and the rate of output as represented by annual volume of output of production.

Data tested consists of direct factory cost per unit, fixed factory cost per unit, and total factory cost per unit. Correlation between total business costs per unit and output volumes were also tested.

5.1. Data

Data for annual average direct, fixed and total cost per unit of production at the factory is taken from Appendix E section 1, Table 1.4. (See 1.1 for source and adjustment)

Data for the business as a whole is taken from Appendix C section 4, Table 4.8, deflated average sales and costs per unit. (See 4.2 for notes on source and adjustments)

Annual volumes of production are taken from Appendix C, Table 4.1. (See 4.2 for notes and adjustments)

5.2. Analyses

The experiment tests for a linear correlation between annual average unit cost and annual output volume over the period 1965/66 and 1976/77.

Model: $y = a + bx$ where y = unit cost, x = output volume

a,b parameters of the model.

Linear regression analysis is used in the usual way. (See main report, 4.3.1.)

Table 5.1

Results of tests of linear correlation between unit cost and volume of output

Data	Trend line	C	F	Sig. level
Factory direct cost per unit	$y = 28.47 + 0.0476x$	.917	47.6	0.1%
Factory fixed cost per unit	$y = -6.31 + 0.0112x$	.753	11.8	1.0%
Total factory cost per unit	$y = 22.16 + 0.0591x$	.917	47.9	1.0%
Total business direct cost per unit	$y = 420.16 - 0.0242x$	-.389	1.78	Not sig. at 5%
Total business fixed cost per unit	$y = 394.25 - 0.0436x$	-.882	35.1	0.1%
Total business total cost per unit	$y = 809.44 - .0667x$	-.790	16.6	1.0%

5.3. Results (See Table 5.1.)

The direct cost per unit of production at the factory is significantly correlated with output volume, at a significance level of 0.1%. The correlation is positive, i.e. direct cost per unit increases with volume.

Fixed cost per unit at the factory is also positively correlated with output volume, at a 1.0% level of significance.

As a result, total cost per unit at the factory is positively correlated with output volume, at a level of significance of 1.0%

Results for the total business unit costs, however, show a significant negative correlation between fixed cost per unit and output volume, no significant correlation between direct cost per unit and output volume, with the result that total cost per unit is negatively correlated with output volume at a 1.0% level of significance.

5.4. Conclusions

The average unit cost of production at the factory, in particular, the element formed by direct cost, is significantly positively correlated with volume of output.

This does not necessarily imply a cause and effect relationship, but may be due to the presence of a third variable.

However, this result may be contrasted with that for the total business unit cost, which is negatively correlated with output volume.

6. Width of range of models in production

6.1. Data (See Tables 6.1 - 6.3)

Data consists of the number of models being manufactured in each year, for MIG and TIG, and the total for the year, plus total cost per unit of production, from part 1 of this Appendix (See Table 1.4)

6.2. Analyses

a) Linear regression techniques are used to test whether there is a statistically significant trend in the number of models produced annually, over the period 1965/66 - 1976/77, using the model

$$y = a + bx$$

where y = number of models produced

x = time elapsed in years, i.e. 1965/66 x = 1

1976/77 x = 12

a, b are parameters of the model.

b) Linear regression techniques are used to test the correlation between the number of models produced and the total cost per unit of production in any year.

<u>Table 6.1</u>

<u>Raw data on numbers of models produced each year - MIG</u>

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
					MIG - Models produced							
MRCS 200 B	X	X	X	X	X	X						
SMR 200				(X)	X	X	X	X	X	X	X	X
Lynxpak 200										X	X	X
Autolynx 100				X	X	X	X	X	X	X	X	
CO_2					X	X	X	X	X	X	X	X
130								X	X	X	X	X
SMR 225						X	X	X	X	X	X	
TM 225												X
SMR 250								X	X	X		
SMR 300						X	X	X	X	X		
SMR 350						(X)	X	X	X	X	X	
TM 350											X	X
SPR	X	X	X	X	X	X	X	X	X	X	X	X
SMR 400	X	X	X	X	X	X	X	X	X	X		
SMR 500						X	X	X	X	X	X	X
STR 650		X	X	X	X	X	X	X	X	X	X	X
MIG - Total	3	4	4	5	7	10	10	12	12	13	11	9

NB - (X) indicates that a model is introduced but only 1-2 made, not in general production

<u>Table 6.2</u>

<u>Raw data on numbers of models produced each year - TIG</u>

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
						TIG - number of models produced						
AMR 150	X	X	X	X	X	X	X	X	X	X		
AMR 250	X	X	X	X	X	X	X	X	X	X	X	
AMR 400	X	X	X	X	X	X	X	X	X	X		
TT DC 250											X	X
ADR 200	X	X	X	X	X	X	X	X	X			
ADR 300	X	X	X	X	X	X	X	X	X	X	X	X
AC/DC 375											X	X
MR 375	X	X	X	X	X	X	X	-	X			
TDC 150							X	X	X	X	X	X
TAR 300								X	X	X	X	X
DAC 240						X	X	X	X			
DAC 320			X	X	X	X	X	X	X	X		
TA AC/DC 320											X	X
TT AC 350											X	X
MNR 300	X	X	X	X	X	X	X	X	X	X		
MNR 400	X	X	X	X	X	X	X	X	X	X	X	X
MNR 650	X	X	X	X	X	X	X	X	X	X	X	X

Table 6.2 cont.

Raw data on numbers of models produced each year - TIG

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
	TIG - number of models produced											
TA DC 525											X	X
TA DC 825											X	X
MR 500								X				
TOTAL TIG	9	9	10	10	10	11	12	13	13	10	12	11
SUBMERGED ARC	1	1	3	3	3	3	3	4	5	3	4	3
PLASMA	1	3	3	3	4	4	4	4	3	3	2	2
TOTAL TIG & PLASMA	11	13	16	16	17	18	19	21	21	16	18	16

Table 6.3

Numbers of models produced each year (Total)

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MIG	3	4	4	5	7	10	10	12	12	13	11	9
TIG & PLASMA	11	13	16	16	17	18	19	21	21	16	18	16
TOTAL	14	17	20	21	24	28	29	33	33	29	29	25
				Annual average cost per unit (deflated) £								
Total cost/unit (Factory)	190	160	178	227	251	227	209	237		245	261	301
Total cost/unit (Total business)	679	670	579	539	513	561	568	652	501	529	535	538

6.3 Results

Table 6.4

Data	Linear regression line	C	F	Sig. level
Trend in number of models produced	y = 16.530 + 1.329x	.78	15.8	1.0%
Correlation between no. of models & total cost per unit (whole business)	y = 699.402 - 5.079x	.54	4.11	Not sig. at 5%
Correlation between no. of models & factory cost per unit	y = 128.530 + 3.986x	.58	4.58	Not sig. at 5%

i.e. There has been a significant overall increase in the number of models produced, although there has been some reduction in the past three years.

However there is no evidence to support a correlation between the number of models in production and the total cost of production, either in the factory or for the business as a whole.

6.4. Conclusions

On the basis of the above evidence, width of range has not been a contributory factor to the trends in total cost per unit of production.

7. Investigation of changes in the product mix over the period 1965/66 to 1976/77

The analyses consider the product mix from three different aspects:

a) By process - proportions of MIG and TIG in the product mix.

b) By type of equipment - the proportion of rectifiers to other equipment in the product mix.

c) By size of set - the proportion of light, medium and heavy in the product mix.

7.1. Data, sources and adjustments

a) Proportions of MIG and TIG

Proportions of each by volume of output of rectifiers are calculated from the data on numbers of output of each type of machine. (See Appendix C.4, Table 4.1 for data and 4.2.1 for source of data, adjustment, etc.

b) Proportion of rectifiers in the product mix

The arc welding equipment produced by BOC Arc Equipment includes rectifiers, other equipment (torches, wire feed units, hoses, etc.) and spares. In order to test whether the proportion formed by rectifiers has changed over the period in question, each proportion is calculated by value.

The source of data is the analysis of sales and contribution by product group.

An adjustment has to be made for MIG, to allocate packages back into rectifiers and equipment for 1974/75 onwards. Thus, for MIG, the category of rectifiers is formed by power sources + autolynx, plus 60% of packages.

Data for Plasma is divided into cutting equipment, welding equipment, and spares. For this exercise, 'welding equipment' is taken to contain half rectifiers and half other equipment, by value.

Hence for TIG and PLASMA, the category of rectifiers is formed by

Power Sources + Plasma cutting equipment, +

½ Plasma welding equipment.

The proportions, by value, formed by rectifiers of all equipment are then calculated for MIG and TIG separately and for both together.

c) Proportions formed by size of set

Again using data on annual volume of output of each type of machine (see Appendix C.4, Table 4.1), machines are classified by a category of size (in terms of output current of the machine) and the proportion of sets in each category is calculated for each year.

7.2. Analyses

In each case the proportion formed by certain categories in the product mix are tested for any significant changes over the period in question, using the techniques of linear regression analysis described in 1.2.

The model used in each case is

$y = a + bx$, a and b are parameters of the model where y is the proportion represented by that category,

x is elapsed time, i.e. 1965/66 $x = 1$, ...
1976/77 $x = 12$

7.3. Results

a) Proportion by process

Linear regression analysis of the proportion of MIG in the total product mix, by volume, gives

$$y = 0.582 + 0.00790x$$

where y is the proportion of MIG/MIG,TIG,PLASMA

$C = 0.45$, $F = 2.5$, not significant at a 5% level

i.e. although there has been a slight overall increase in the proportion of MIG in the product mix, this trend is not statistically significant. The current proportion is estimated to be 0.676 approximately.

b) Proportion by type of equipment

i) For MIG and TIG together

Linear regression analysis of the proportion of rectifiers in the product mix of all equipment, by value, gives

$$y = 0.429 - 0.000140x$$

where y is the proportion of rectifiers in the product mix, by value

$C = 0.02$, $F = 0.004$, not significant at a 5% level.

i.e. there is no trend in the porportion of rectifiers in the product mix, by value 1965/66 to 1976/77.

ii) For MIG alone

Linear regression analysis gives

$$y = 0.422 - 0.00248x$$

C = .20, F = 0.4, not significant at a 5% level.

iii) For TIG alone

Linear regression analysis gives

$y = 0.4397 + 0.00287x$

C = 0.294, F = 0.6 not significant at a 5% level.

Table 7.1

Product mix by MIG, TIG and PLASMA

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Numbers of rectifiers produced												
MIG	1295	1653	1600	2065	2508	2389	2184	2553	3091	2466	2454	3068
TIG, PLASMA & AUTOMATICS	941	1027	1548	1588	1173	946	1003	1097	1751	1666	1506	1393
TOTAL	2236	2680	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461
Proportions by volume												
MIG	.58	.62	.51	.56	.68	.72	.68	.70	.64	.60	.62	.69
TIG, PLASMA & AUTOMATICS	.42	.38	.49	.44	.32	.28	.32	.30	.36	.40	.38	.31

Table 7.2

Raw data and analysis of BOC Arc Equipment sales by product group

Value of sales £'000

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MIG												
Welding equipment	176	279	296	396	420	336	382	573	612	598	629	717
Power Sources	351	269	288	405	490	377	391	608	629	385	351	403
Autolynx	-	-	-	34	211	308	236	304	292	219	338	176
Spares	279	190	166	215	284	270	277	335	-	-	-	-
Packages										273	359	771
Repairs						21	20	21				
Rentals			17	17	5	8	8	11		3		
Consumables			35	50	64	67	82	102	154			
Services			6	11	14	24	19	25				
KAT			-									32
Specials			-									119
TOTAL MIG	806	738	808	1128	1488	1411	1415	1979	1687	1478	1677	2218

cont./

Table 7.2 cont.

Raw data and analysis of BOC Arc Equipment sales by product group

Value of sales £'000

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
TIG												
Welding equipment	188	137	144	151	171	162	226	269	355	417	458	615
Power Sources	232	216	285	360	298	299	358	500	613	686	749	1025
Spares	147	151	107	107	146	138	132	127	-	-	-	-
Source			3	6	8	21	26	26				
Rentals			4	-	2	2	3	6				
Specials												13
Consumable spares			54	58	68	99	111	106				
TOTAL TIG	567	504	597	682	693	721	856	1034	968	1103	1207	1653
PLASMA												
Cutting equip.						6	26	43	111	96	104	113
Welding equip.						23	45	66	70	78	91	96
Spares						4	15	33	-	-	-	-
TOTAL PLASMA						33	86	142	181	174	195	209

Table 7.3

Product mix by proportions of rectifiers in total equipment

Sales & proportion of sales in each category

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
MIG						Sales £'000						
'Rectifiers'	351	269	288	439	701	685	627	912	921	768	904	1162
Other equipment	176	279	296	396	420	336	382	573	612	711	773	1058
Spares*, rental etc.	279	190	224	293	367	390	406	497	811	743	776	959
TOTAL	806	738	808	1128	1488	1411	1415	1982	2344	2222	2453	3179
MIG						Proportions						
Rectifiers	.43	.36	.36	.39	.47	.48	.44	.46	.39	.35	.37	.37
Equipment	.22	.37	.37	.35	.28	.24	.27	.29	.26	.32	.31	.33
Spares*, etc.	.35	.27	.27	.26	.25	.28	.29	.25	.35	.33	.32	.30
TIG & PLASMA						Sales £'000						
'Rectifiers'	232	216	285	360	298	316	406	576	759	821	898	1197
Equipment	188	137	144	151	171	174	249	302	390	456	504	663
Spares*, etc.	147	151	168	171	224	264	287	298	415	491	520	679
TOTAL	567	504	597	682	293	754	942	1176	1564	1768	1922	2539

cont/

Table 7.3 cont.

Product mix by proportions of rectifiers in total equipment

Sales & proportion of sales in each category

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
TIG						Proportions						
Rectifiers	.41	.43	.48	.53	.43	.42	.43	.49	.48	.46	.47	.47
Welding equipment	.33	.27	.24	.22	.25	.23	.26	.26	.25	.26	.26	.26
Spares etc.	.26	.30	.28	.25	.32	.35	.31	.25	.27	.28	.27	.27
				Proportions - MIG & TIG together								
Rectifiers	.42	.39	.41	.44	.46	.46	.44	.47	.43	.40	.41	.41
Equipment	.26	.33	.31	.30	.27	.24	.27	.28	.26	.29	.29	.30
Spares etc.	.32	.28	.28	.26	.27	.30	.29	.25	.31	.31	.30	.29

* Value of spares reallocated to MIG, TIG & PLASMA for 1973/74 onwards. (See Appendix C.4, Table 4.5 and section 4.2.3 for data and adjustments)

Table 7.4

Product mix by size of set - all sets (MIG & TIG)

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
	Numbers produced in each category											
Up to 200A	1354	1407	1252	1301	1691	1658	1639	1714	1994	1362	1469	1491
201 - 300A	136	136	340	339	306	777	594	884	1339	796	387	638
301 - 400A	519	814	1065	1435	1068	557	481	603	735	1173	1155	1502
Over 400A	227	323	491	578	616	343	473	449	774	801	949	830
TOTAL	2236	2680	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461
	Proportions in each category											
Up to 200A	.61	.53	.40	.36	.46	.50	.51	.47	.41	.33	.37	.33
201 - 300A	.06	.05	.11	.09	.08	.23	.19	.24	.28	.19	.10	.14
301 - 400A	.23	.30	.34	.39	.29	.17	.15	.17	.15	.29	.29	.34
Over 400A	.10	.12	.15	.16	.17	.10	.15	.12	.16	.19	.24	.19
Up to 300A	.67	.58	.51	.45	.54	.73	.70	.71	.69	.52	.47	.47

Table 7.5

Product mix by size of set - MIG & TIG separately

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
						Numbers produced - MIG						
Up to 200A	1210	1211	1012	1128	1535	1499	1392	1543	1680	1222	1413	1331
201 - 300A	-	-	-	-	-	398	238	465	609	175	20	345
301 - 400A	25	305	331	544	574	224	252	298	364	626	580	915
Over 400A	60	137	257	393	399	268	302	247	438	443	441	477
TOTAL	1295	1653	1600	2065	2508	2389	2184	2553	3091	2466	2454	3068
Up to 200A						Proportions - MIG						
Up to 200A	.93	.73	.63	.55	.61	.63	.64	.60	.54	.50	.58	.43
201 - 300A	-	-	-	-	-	.17	.11	.18	.20	.07	.01	.11
301 - 400A	.02	.19	.21	.26	.23	.09	.11	.12	.12	.25	.24	.30
Over 400A	.05	.08	.16	.19	.16	.11	.14	.10	.14	.18	.18	.16
						TIG - Numbers produced						
Up to 200A	144	196	240	173	156	160	247	171	314	140	56	160
201 - 300A	136	136	340	339	306	376	356	419	730	621	367	293
301 - 400A	434	439	594	720	325	196	173	224	296	505	522	449
Over 400A	75	94	85	65	103	50	20	71	106	126	323	363
PLASMA & *Automatics*	152	162	289	291	283	162	207	212	305	274	238	128

cont./

Table 7.5 cont.

Product mix by size of set - MIG & TIG separately

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
					TIG - numbers produced cont.							
TOTAL	941	1027	1548	1588	1173	944	1003	1097	1751	1666	1506	1393
					TIG - proportions in each category							
Up to 200A	.15	.19	.16	.11	.13	.17	.25	.16	.18	.08	.04	.11
201 - 300A	.15	.13	.22	.21	.26	.40	.35	.38	.42	.37	.24	.21
301 - 400A	.46	.43	.38	.46	.28	.21	.17	.20	.17	.30	.35	.32
Over 400A	.08	.09	.05	.04	.09	.05	.02	.06	.06	.08	.21	.26
PLASMA & Automatics	.16	.16	.19	.18	.24	.17	.21	.20	.17	.17	.16	.09

Table 7.6

Trends in proportion of product mix by size of set

Classification	Trend line	C	F	Sig. level
1. All sets (MIG and TIG				
Up to and incl. 200A	y 0.541 - 0.016x	0.64	7.03	2.5%
201 - 300A	y = 0.072 + 0.0114x	0.54	4.05	Not sig. at 5%
301 - 400A	y = 0.278 - 0.00283x	Not sig. at 5%		
Over 400A	y = 0.103 + 0.00787x	0.69	9.18	2.5%
Up to and incl. 300A	y = 0.619 - 0.00503x	0.17	0.3	Not sig. at 5%
2. MIG only				
Up to 200A	y = 0.792 - 0.0274x	-0.79	16.5	1%
201 - 300A	y = 0.191 - 0.0175x	-0.56	4.6	Not sig. at 5%
301 - 400A	y = 0.115 + 0.00979x	0.42	2.1	Not sig. at 5%
Over 400A	y = 0.0888 + 0.00693x	0.57	4.8	Not sig. at 5%
3. TIG only				
Up to 200A	y = 0.186 - 0.00640x	-0.42	2.1	Not sig. at 5%

cont/

Table 7.6 cont.

Trends in proportion of product mix by size of set

Classification	Trend line	C	F	Sig. level
3. TIG only cont.				
201 - 300A	$y = 0.183 + 0.0146x$	0.52	3.6	Not sig. at 5%
301 - 400A	$y = 0.412 - 0.0157x$	-0.53	3.9	Not sig. at 5%
Over 400A	$y = 0.0170 + 0.0114x$	0.57	4.9	5%

c) Proportion by size of set

Results from the analyses (Table 7.6) show a significant swing away from the very small size of set (under 200A), with significant increase in the proportion of sets which are over 400A, but no trend in proportion formed by the middle amp ranges.

Taking MIG separately, there has been a swing away from sets in the 200A range caused by phasing out of the MRCS 200B and SMR 200, and the higher current ratings of the new SMR models (see E.4., Table 4.1). The effect of the uprating of current in later models is that of a slight shift in each category, with a resulting slight increase in the proportion of sets in the heavy end of the range.

Taking TIG separately, there has been a recent decline in sets in the under 200A range (not significant overall), and a corresponding increase in proportion of sets in the higher current ratings. Again this is due to the replacement of existing models with those of a higher amp rating (E.4, Table 4.1).

Although the trends for MIG and TIG sets separately are not all statistically significant, their investigation sheds light on the reasons for the overall trends and their effect on average unit cost.

7.4. Conclusions

There has been no significant change in the product mix over the period 1965/66 to 1976/77 with respect to the proportions of MIG to TIG (by volume), or the proportion of rectifiers in the total equipment mix (by value).

However, there have been statistically significant trends in the product mix by size of set, with swings away from the lower end of the range (up to 200A), and towards the heavy end (over 400A). These trends are due to increased current ratings of replacement models which has occurred in both the MIG and TIG product ranges.

8. Investigation of any increase in complexity of the welding rectifier over the period 1965/66 to 1976/77

8.1. Data and adjustments

In order to investigate any trend in the average complexity of a rectifier, each model was given a complexity rating by the chief engineer.

Numbers produced were then weighted by the complexity rating of the product to give the number of units of complexity produced each year.

8.2. Analysis

The above data was used to calculate the weighted average number of complexity units per rectifier for each year. Linear regression was used to test for any trend in the average number of complexity units over the period 1965/66 - 1976/77.

Model $y = a + bx$

where y = no. of complexity units per rectifier produced

x = elapsed time (years)

a, b parameters of the model

8.3. Results

i) Trend in annual average number of complexity units per rectifier

a) MIG alone

Linear regression gives

$y = 2.227 + 0.0970x$

$C = 0.89$, $F = 37.33$ significant at 0.1%

b) TIG alone

Linear regression gives

$y = 3.0223 - 0.0211x$

$C = 0.46$, $F = 2.70$ not significant at 5%

c) Both MIG and TIG together

$y = 2.554 + 0.0502x$

$C = 0.79$, $F = 16.7$ significant at 1.0% level

$y_1 = 2.604$, $y_{12} = 3.156$, $r = .0174$

8.4. Conclusions

There has been a significant increase in complexity of the product over the period 1965/66 to 1976/77, as measured by the average number of complexity units per rectifier produced.

Surprisingly, this is due to a trend for increased average complexity in the MIG range; average complexity per unit of a TIG rectifier increases until 1971/72 and then declines again to pre 1965/66 levels.

This is partly due to the introduction of the simpler TAR 300, TDC 150 models, but also to the decline in demand for the large, complex AMR range and its successor, the TT DC 250, also to the decline in production of submerged arc machines.

The trend for increased complexity in MIG is due partly to the move away from the simple 200 amp set (MRCS 200 B and SMR 200) to the more complex members of the SMR range, and partly due to the introduction of the more sophisticated Autolynx and Lynxpak 200 range.

Table 8.1

Raw data for investigation of average complexity of a rectifier over the period 1965/66 to 1976/77 - MIG

Complexity rating ranges from 1 (simple) to 5 (highly complex)

	MIG - Numbers produced											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Complexity rating 1												
None												
Rating 2												
SMR 200	10	11	12	26	176	589	502	752	861	410	290	392
MRCS 200B	1200	1200	1000	750	669	114						
STR 650		67	117	222	230	77	49	42	125	128	117	64
TOTAL	1210	1278	1129	998	1075	780	551	794	986	538	407	456
Rating 3												
SMR/TM 225						246	112	157	169	84	20	345
SMR 250								41	53	18	-	-
SMR 300						152	126	267	387	73		

cont./

Table 8.1 cont.

Raw data for investigation of average complexity of a rectifier over the period 1965/66 to 1976/77 - MIG

MIG - Numbers produced

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Rating 3 cont.												
SMR/TM 350						1	149	206	269	546	580	915
SMR 400	25	305	331	544	574	223	103	92	95	80	-	-
SMR 500						54	197	125	238	273	274	365
TOTAL	25	305	331	544	574	676	687	887	1211	1074	874	1625
Rating 4												
All Autolynx				352	690	796	890	791	819	721	847	700
Lynxpak 200										91	276	239
SPR	60	70	140	171	169	137	56	81	75	42	50	48
TOTAL	60	70	140	523	859	933	946	872	894	854	1173	987
Rating 5												
None												
TOTAL MIG (Normal units)	1295	1653	1600	2065	2508	2389	2184	2553	3091	2466	2454	3068

Table 8.2

Raw data - TIG

TIG - numbers produced in each complexity rating

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Rating 1												
TAR 300								51	139	64	116	120
MNR 300	26	26	71	112	84	99	36	32	123	21	-	-
MNR 400	154	159	293	293	238	118	124	186	146	424	198	108
MR 500								19				
MNR 650	75	94	85	65	103	50	20	52	106	126	153	35
TA DA 525											112	193
TOTAL	255	279	449	470	425	267	180	340	514	635	579	456
Rating 2												
TDC 150							35	60	150	107	46	140
DAC 240						60	30	38	30			
TA DC 825											55	45
TOTAL	-	-	-	-	-	60	65	98	180	107	101	185

cont./

Table 8.2 cont.

Raw data - TIG

TIG - numbers produced in each complexity rating

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
Rating 3												
TA AC/DC 320											66	89
TT AC 350											42	40
DAC 320			21	96	62	46	7	5	79	65	1	
MR 375	250	250	250	300	11	20	25	-	15			
TOTAL	250	250	271	396	73	66	32	5	94	65	109	129
Rating 4												
AMR 150	114	150	150	54	64	28	102	8	56	2	-	-
AMR 250	60	60	67	33	10	15	37	13	30	49	20	-
AMR 400	30	30	30	31	14	12	17	33	56	16	1	-
ADR 200	30	32	60	89	61	115	108	84	53			
ADR 300	50	50	202	194	212	205	253	285	408	487	184	94
TT AC/DC 375											217	302

cont./

Table 8.2 cont.

Raw data - TIG

	TIG - numbers produced in each complexity rating											
	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
All PLASMA	2	26	40	42	48	31	11	29	64	43	15	31
All Sub. arc	150	150	279	279	266	147	198	202	296	262	233	117
TOTAL	436	498	828	722	675	553	726	654	963	859	670	544
Rating 5												
TT DC 250											47	79
TOTAL TIG	941	1027	1548	1588	1173	946	1003	1097	1751	1666	1506	1393

Table 8.3

Annual number of complexity units produced

	65/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77
	Number of complexity units											
MIG	2735	3751	3811	5720	7308	7320	6947	7737	9181	7714	8128	9735
TIG	2749	3021	4574	4546	3344	2801	3310	3167	5008	4480	4023	3784
TOTAL	5484	6772	8385	10266	10652	10121	10257	10904	14189	12194	12151	13519
	Average complexity units/rectifiers produced											
MIG	2.11	2.27	2.38	2.77	2.91	3.06	3.18	3.03	2.97	3.13	3.31	3.17
TIG	2.92	2.94	2.95	2.87	2.85	2.96	3.30	2.89	2.86	2.69	2.67	2.72
TOTAL	2.45	2.53	2.66	2.81	2.89	3.03	3.22	2.99	2.93	2.95	3.07	3.03

Appendix F

Use of the experience curve model for projecting average price and unit cost of a rectifier in strategic plans for 1979/84.

Index

1. Unit cost reduction required for BOC Arc Equipment over the period 1979/84 in order to achieve strategic aims.
    1.1 Assumptions and methods
        1.1.1 Specific assumptions
        1.1.2 Method used in calculations
    1.2 Results

2. Projections for strategic plans 1979/84
    2.1 Assumptions and methods
        2.1.1 Estimation of projected annual output volumes from projected annual value of sales 1979/84
        2.1.2 Calculation of unit costs from projected volumes, using experience curve model
        2.1.3 Estimation of projected profits using projected value of sales and costs
        2.1.4 Additional assumptions - unit cost reduction
        2.1.5 Additional assumptions - price reductions
    2.2 Results
    2.3 The effect of proposed price reductions on profits, in addition to proposed cuts in direct costs of the products

3. Comparison of unit cost reduction required by BOC AE to achieve specified strategic aims with that planned by

the company in strategic plans for 1979/84

Index of Tables

Appendix F

Use of the experience curve model for projecting average price and unit cost of a rectifier in strategic plans for 1979/84.

The work consists of three main parts:

1) Estimation of the extent of unit cost reduction necessary for Boc Arc Equipment over the period 1979 to 1984 in order to:

a) Match unit cost of major competitors by 1984

b) Maintain the current differential between unit costs of Boc Arc Equipment and major competitors (i.e. 1977/78 differential).

The exercise consists of a simulation of unit cost reduction taking place in Boc Arc Equipment and a typical major competitor, if unit cost is modelled by the experience curves fitted in the experimental work to data from Boc, and from BEAMA data giving average price of a rectifier in the U.K. (See 5.) The simulation covers the period 1966/77, as well as projections for 1979/84, under various assumptions of volume growth for the competitor.

2) Projections of sales, costs and profit margins for Boc Arc Equipment over the period 1979/84, if planned cost and price reduction takes place.

3) Comparison of unit cost reduction required for Boc Arc Equipment with that planned by them.

1. Unit cost reduction required for Boc Arc Equipment over the period 1979/84 in order to achieve strategic aims

Aims: a) Match competitors unit cost by 1984

b) Maintain 1977/78 differentials between unit cost for Boc Equipment and major competitors.

The approach to the problem consisted of a simulation of unit cost reduction for rectifiers produced by Boc Arc Equipment and a major competitor over the period 1966/77, and projections for 1978/84, under varying assumptions made about the volume growth and relative size of the competitor. The assumptions were those suggested by the corporate planning manager, designed to simulate the situation between Boc Arc Equipment and a typical large European manufacturer. (e.g. ESAB)

The assumptions and methods used in calculations are given in 1.1, calculations and results in 1.2,

1.1 Assumptions and methods

1.1.1 Specific assumptions

a) Both Boc Arc Equipment and the competitor have equal cumulative output of 26508 in 1966 (the cumulative output estimated for Boc Arc Equipment in the experimental work reported in Appendix C, 3.2.7).

b) Both start in 1966 with equal unit costs of £500. (for ease of calculation).

c) For the period 1966/77, annual output volumes for Boc Arc Equipment are the actual amounts, taken from data in Appendix C (Table 3.1).

d) For 1978/84, annual output volume growth for Boc Arc Equipment is assumed to be 6% p.a.

e) The general assumption for the pattern of growth for the competitor is that their volume of output is equal to that of Boc Arc Equipment in 1966. The other company then grows rapidly over the period 1966/72 to become much larger than Boc by 1972, in terms of output volume. From 1972/77 growth in the other company is either equal to or a little higher than that in Boc Arc Equipment. From 1979 to 1984 volume growth in the other company is equal to or higher than that of Boc Arc Equipment, with a top growth rate of 20% p.a. This gives the following specific assumptions for volume growth in the other company:

i) In 1966, volume of output equals that of Boc Arc Equipment.

ii) From 1966/72, volume growth is such that the volume of output in 1972 is larger than that of Boc by factors of 2, 1.33 and 4, respectively. This is expressed as the relative competitive position (RCP) of Boc to the other company, in terms of annual output volume, giving alternative RCPs of 0.5. 0.75 and 0.25 respectively.

iii) From 1972/77 annual volume growth is either the same as that in Boc, or that of Boc plus 2% p.a.

iv) 1978/84, volume growth takes place at alternative rates of 6%, 8%, 10% and 20% p.a.

See Table F.1 for volumes of output resulting from these assumptions.

f) Unit cost reduction in Boc Arc Equipment takes place in line with the 86.5% curve fitted to data for 1966/77. (Appendix C.3, Table 3.11) i.e. parameter b = 0.2085.

g) Unit cost reduction in the other company takes place in line with the 81.1% curve fitted to BEAMA data for average price of a rectifier in the U.K. over the period 1963/77. (Appendix C.2.2, Table 2.7) i.e. Parameter b = 0.3023.

1.1.2 Method used in calculations.

The volumes calculated from the above assumptions were used to calculate cumulative output for Boc and For the other company, under the varying assumptions. (Table F.2)

The projected cumulative output was then used to calculate unit cost for the relevant years, from the models described in 1.1.1 (f) and (g) The form of the model used to calculate unit cost was

$$\frac{yi}{yj} = \frac{(xj)}{(xi)}^{b}$$

where xi = cumulative output in year i

yi = unit cost in year i

b = parameter of experience curve b

(Table F.3)

The projected unit cost for the other company in 1984 was then compared with the estimated unit cost for Boc Arc Equipment in 1978, and the requisite cost reduction calcu;ated as a percentage of costs in 1978.
(Table F.4)

1.2 Results

For estimate of unit cost reduction required by Boc Arc Equipment over the period 1979/84, see Table F.4

The following points are noted.

a) The percentage cost reduction required over the period 1979/84, for Boc Arc Equipment to match competitors' unit costs by 1984, varies between 30% and 48%.

The amount required is more sensitive to the relative size of the company in 1972, than to subsequent growth rates.

Table F.1

Volumes of output for BOCAE, and for a major competitor under differing assumptions of volume growth

	Boc AE	Competitor - Case I (RCP of 0.5 by 1972)	Competitor - Case II (RCP of 0.75 by 1972)
1966	2538	2538	2538
67	2378	3177	2766
68	3148	3817	3014
69	3653	4456	3284
70	3681	5095	3578
71	3335	5735	3899
72	3187	6374 (RCP = 0.5)	4249 (RCP = 0.75)

	Boc AE	Case I: Growth rates 1972-77: Same as Boc	Case I: 2% more than Boc	Case II: Growth Rates 1972-77: Same as Boc	Case II: 2% more than Boc
1973	3650	7300	7427	4867	4951
74	4842	9684	10001	6456	6667
75	4132	8264	8734	5509	5823
76	3960	7920	8545	5280	5697
77	4461	8922	9797	5948	6532

Projected volumes 1978-84, under differing growth rates

	Boc AE	Competitor-Case I: 6% pa	8% pa	10% pa	20% pa	Competitor-Case II: 6% pa	8% pa	10% pa	20% pa
1977	4461	8922	9797	9797	9797	5948	6532	6532	6532
78	4729	9457	10581	10777	11756	6305	7055	7185	7838
79	5012	10024	11427	11854	14108	6683	7619	7904	9406
80	5313	10626	12342	13040	16929	7084	8228	8694	11287
81	5632	11264	13329	14344	20315	7509	8887	9563	13545
82	5970	11940	14395	15778	24378	7960	9598	10520	16254
83	6328	12656	15547	17356	21254	8437	10365	11572	19504
84	6708	13415	16791	19092	35104	8943	11195	12729	23405
RCP 1984		0.5	0.40	0.35	0.19	0.75	0.60	0.53	0.29

	Competitor-Case III (RCP of 0.25 by 1972)			
1966	2538			
67	3321			
68	4346			
69	5688			
70	7444			
71	9741			
72	12748			
	Growth rates 1972-77			
	Same as Boc	2% more than Boc		
1972	12748	12748		
73	14600	14855		
74	19368	20003		
75	16528	17470		
76	15840	17092		
77	17844	19596		
	Projected volumes 1978-84			
	6% pa	8% pa	10% pa	20% pa
1977	17844	19596	19596	19596
78	18915	21164	21556	23515
79	20049	22857	23711	28218
80	21252	24685	26082	33862
81	22527	26660	28690	40634
82	23879	28793	31560	48761
83	25311	31096	34715	58513
84	26830	33584	38187	70215
RCP 1984	0.25	0.20	0.18	0.095

Table F.2

Cumulative output for Boc Arc Equipment

and for major competitor, under differing assumptions of volume growth.

	Cumulative output (Units)				
	1966	1972	1977	1978	1984
Boc Arc Equipment	26,508	45,890	66,395	71,124	106,087
Major competitor					
Case I (RCP 1972 0.5)					
Growth rate 1978-84 6%	26,508	55,162	97,252	106,709	176,634
8%	26,508	55,162	99,666	110,247	194,078
10%	26,508	55,162	99,666	110,443	201,907
20%	26,508	55,162	99,666	111,422	251,510
Case II (RCP 1972 0.75)					
Growth rate 1978-84 6%	26,508	47,298	75,358	81,663	128,279
8%	26,508	47,298	76,968	84,023	139,915
10%	26,508	47,298	76,968	84,153	145,135
20%	26,508	47,298	76,968	84,806	178,207
Case III (RCP 1972 0.25)					
Growth rate 1978-84 6%	26,508	69,796	153,976	172,891	312,739
8%	26,508	69,796	158,812	179,976	347,651
10%	26,508	69,796	158,812	180,368	363,313
20%	26,508	69,796	158,812	182,327	462,530

Table F.3

Unit costs for Boc Arc Equipment and

for major competitor under differing assumptions of volume growth

	Unit cost (£)				
	1966	1972	1977	1978	1984
Boc Arc Equipment	500	445.94	412.88	407.00	374.45
Major competitor					
Case I (RCP 1972 0.5)					
Growth rate 1978-84 6%	500	400.35	337.09	327.74	281.28
8%	500	400.35	334.60	324.51	273.36
10%	500	400.35	334.60	324.34	270.10
20%	500	400.35	334.60	323.47	252.69
Case II (RCP 1972 of 0.75)					
Growth rate 1978-84 6%	500	419.47	364.21	355.44	309.94
8%	500	419.47	361.88	352.38	301.88
10%	500	419.47	361.88	352.21	298.55
20%	500	419.47	361.88	351.39	280.53
Case III (RCP 1972 of 0.25)					
Growth rate 1978-84 6%	500	372.77	293.24	283.12	236.53
8%	500	372.77	290.50	279.69	229.06
10%	500	372.77	290.50	279.50	226.02
20%	500	372.77	290.50	278.59	210.06

Table F.4

Results of simulation

a) Percentage cost reduction required over the next 5 years by Boc Arc Equipment to match competitors costs by 1984.

RCP of competitor in 1972	Growth rate 1978-84			
	6%	8%	10%	20%
I RCP = 0.5	30.9%	32.8%	33.6%	37.9%
II RCP = 0.75	23.8%	25.8%	26.6%	31.1%
III RCP = 0.25	41.9%	43.7%	44.5%	48.4%

b) Percentage cost reduction over the next 5 years required by Boc Arc Equipment to maintain current (1977) differentials).

RCP of competitor in 1972	Growth rate 1978-84			
	6%	8%	10%	20%
I RCP = 0.5	11.4%	12.6%	13.3%	17.4%
II RCP = 0.75	11.2%	12.4%	13.1%	17.4%
III RCP = 0.25	11.4%	12.4%	13.1%	16.8%

DAMAGED

TEXT

IN

ORIGINAL

c) The percentage cost reduction required for Boc Arc Equipment to maintain 1977/78 differentials in unit cost, relative to the other company, over the period 1979-1984 varies between 11% and 17.5%, being more sensitive to the growth rates of other company since 1977, than to RGP in 1972.

2). Projections under strategic plan 1979/84.

Projected annual values of sales for 1979/84 from the strategic plan were used to estimate annual volume of sales, presuming that the average price declines in line with the experience curve model for average price for Boc Arc Equipment.

Unit costs were then projected under varying assumptions, and from this total cost and hence profits were calculated.

2.1 Assumptions and methods

2.1.1 Estimation of projected annual output volumes from projected annual value of sales 1979/84.

Average price was assumed to decline in line with the experience curve model fitted to Boc data for average sales revenue per unit, 1966-77. (See Appendix C.3.4. Table 3.11)

i.e. equation $y = 4.074 - 0.2685x$

where y = log unit price.

x = log cumulative output

or, $$p = \frac{11851}{C^{0.2685}}$$

where p = average price, C = cumulative output.

Thus, if p_n is the average price in year n, and v_n is output volume in year n, v_n may be calculated using equations

1) $$p_n = \frac{11851}{C_n}$$

2) and $p_n v_n$ = total sales value (deflated to 1970 levels)

where C_n = cumulative output in year n

$= C_{n-1} + v_n$

An iterative method was used to find the approximate volume and price for each year to satisfy the above equations:

a) Select a reasonable figure for volume

b) Calculate p_n from equation (1) (since equation (1) is less sensitive to errors in volume)

c) Use estimation of p_n to find better estimate of v_n from equation (2)

d) Repeat until estimate of v_n fits equations (1) and (2).

(See Table F.5)

2.1.2 Calculation of unit costs from projected volumes, using experience curve model for unit cost for Boc Arc Equipment.

Using cumulative output calculated from projected volumes, the value of total unit cost and fixed cost per unit were estimated using the experience curve model fitted to cost data for Boc Arc Equipment 1966-77. (See Appendix C.3.4 Table 3.11)

i.e. Total unit cost

$y = 3.7218 - 0.2085x$

or Total product cost per unit $= \dfrac{5269.87}{(\text{Cum. output})^{0.2085}}$

Fixed cost per unit - fitted curve has equation

$$y = 4.2056 - 0.3955x$$

or

$$\text{Fixed cost per unit} = \frac{16054.6}{(\text{Cum. output})^{0.3955}}$$

(Table F.5)

2.1.3. Estimation of projected profits using projected value of sales and costs

Total cost was calculted from projected unit cost reflated to 1977-78 levels, and output volumes for each year. These values were subtracted from projected annual sales revenues to give estimates of annual profits for 1979/84 at 1977/78 values.

(Table F.6)

2.1.4. Additional assumptions - unit cost reduction

As well as the unit cost reduction expected from normal cost saving, and projected by the experience curve model, Boc Arc Equipment were hoping to cut the direct cost of a rectifier by approximately 30%.

Since analysis of Boc data for 1966-77 showed no significant reduction in direct cost per unit, it is assumed that any reduction in direct cost will add to total cost reduction projected from an experience curve model.

The direct cost reduction was assumed to happen in a variety of ways:

i) Implementation and effect all in 1981/82

ii) Implementation spread over three years 1981/82, 1982/83, 1983/84 producing 10% reduction in each year.

iii) Reduction in direct cost is not achieved in all products, but achieves an overall 12% reduction in direct cost per unit, spread over the three years 1981/82, 1982/83, 1983/84.

2.1.5. Additional assumptions - price reductions

The effect of the combination price reduction with cost reduction were assessed by calculating the effect on sales revenue and profits. It was assumed that there would be no effect on volumes of sales.

For results see Table F.8

2.2. Results (Tables F.6 and F.7)

a) Estimated total unit cost reduction 1978/84 under normal experience curve model projection is 11.1%.

b) Estimated reduction in average price per unit for Boc rectifier 1978/84 is 14.1%.

c) Consequently, annual profits, although gradually increasing over this period, decline as a percentage of sales.

d) The results of various schemes to reduce direct costs of the product are as follows:

i) 30% reduction in direct cost/unit overall products in 1981/82 gives an overall reduction in total cost per unit over the period 1978/84 of 28.8%, and a predictable sharp increase in profits in 1981/82.

ii) If the 30% reduction is spread over the three year period 1981/82 to 1983/84, overall unit cost reduction is the same as before, with profits increasing gradually from 1981/82 onwards.

iii) If direct cost per unit is reduced by a total of 12% over the three year period 1981/82 to 1983/84, total overall reduction in total cost per unit is 18.2%, again with increase in profits.

2.3. <u>The effect of proposed price reductions on profits, in addition to cuts in direct cost of the products.</u>

See Table F.8 for details of results. The results may be summarised as follows:

a) <u>If direct cost per unit is reduced by 30%, for all products, in 1981/82.</u>

A price reduction of 10% in 1978/79 and a further 10% in 1981/82 will result in low profit margins for the first three years of the plan, followed by a recovery in 1981/82 with the direct cost reduction.

b) <u>If the 30% reduction in direct cost per unit is spread equally over the three year period 1981/82 to 1983/84.</u>

Then i) The same pattern of price reductions as in (a) will give low returns for three years, a loss in 1981/82, and recovery not until 1983/84, the last year of the planning period.

ii) A price reduction of 10% in 1978/79 only will result in a recovery of profit margins by 1981/82, with good margins in 1982/83 and 1983/84.

iii) A price reduction of 12% in 1981/82, profit margins fall briefly in 1981/82, and then recover to good levels in 1982/83 and 1983/84.

c) <u>If direct cost per unit is reduced by 12%, spread over the three year period 1981/82 to 1983/84.</u>

An 8% reduction in price in 1981/82 results in only a slight reduction in profit margins.

Projected sales revenues under strategic plan, estimations of annual average price and output volume for BOCAE, 1979-84

	Year of plan						
	1977/78 (Current)	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
Value of sales £M (MIG and TIG only)	8.022	9.014	9.856	11.535	14.599	17.545	19.066
Deflated using usual index	2.865	3.219	3.520	4.120	5.214	6.266	6.809
Ave price (£) (defl)	589.8	578.0	566.0	553.2	538.2	522.1	506.5
Estimated volume (units)	4858	5569	6218	7447	9686	12,000	13,443
Vol. growth rate	4.2%	14.6%	11.6%	19.8%	30.1%	23.9%	12.0%
Estimation of projected unit costs (at deflated levels)							
Cumulative output	71253	76822	83040	90487	100,173	112,173	125,616
Total unit cost	512.4	505.0	497.6	489.5	480.3	470.4	460.8
Fixed cost per unit	193.4	187.7	182.05	176.0	169.0	161.6	154.6
Direct cost per unit (Total less fixed)	319.0	317.3	315.55	313.5	311.3	308.8	306.2

Projections of total costs and profits 1978/84 for BOCAE

(at 1977/78 values).

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
Volume	4858	5569	6218	7447	9686	12,000	13,443
Average price (£)	1651.3	1618.5	1585.1	1548.9	1507.2	1462.1	1418.3
Sales £M	8.022	9.014	9.856	11.535	14.599	17.545	19.066
			Unit costs at 1977/78 values				
Direct cost/ unit £	894.2	887.7	880.9	873.2	864.0	853.5	842.9
Fixed cost/ unit £	541.5	525.7	509.7	492.7	473.3	452.6	432.8
Total cost/ unit £	1435.7	1413.4	1390.6	1365.9	1337.3	1306.1	1275.7
			Projected total sales, costs and profits				
Sales £M	8.022	9.014	9.856	11.535	14.599	17.545	19.066
Direct costs £M	4.344	4.944	5.477	6.503	8.369	10.242	11.330
Fixed costs £M	2.631	2.927	3.170	3.669	4.584	5.431	5.818
Total costs £M	6.975	7.871	8.647	10.172	12.953	15.673	17.148
Profit £M	1.047	1.143	1.209	1.363	1.646	1.872	1.918
% Profit/Sales	13.1%	12.7%	12.3%	11.8%	11.3%	10.7%	10.1%

Percentage reduction in price per unit 1978-84	14.1%
Percentage reduction in direct cost per unit 1978-84	5.7%
Percentage reduction in fixed cost per unit 1978-84	20.1%
Percentage reduction in total cost per unit 1978-84	11.15%

Projections of profit under proposed reduction in direct cost/unit for 300AE, 1979-84

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
1) Assuming a 30% reduction in direct cost per unit in 1981/82							
Direct cost/ unit (at 1977 /78 values)	894.2	887.7	880.9	873.2	604.8	597.5	590.0
Total direct cost	4.344	4.944	5.477	6.503	5.858	7.169	7.931
Fixed costs (unchanged)	2.631	2.927	3.170	3.669	4.584	5.431	5.818
Total costs	6.975	7.871	8.647	10.172	10.442	12.600	13.749
Profit	1.047	1.143	1.209	1.363	4.157	4.945	5.317
Total cost/ unit	1435.7	1413.4	1390.6	1365.9	1078.1	1050.0	1022.8

Reduction in total product cost 1979/84 = 28.76%

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
2) Assuming 30% reduction in direct cost/unit spread over the three years 1981/82, 1982/83, 1983/84.							
Direct cost/ unit (at 1977/78 values	894.2	887.7	880.9	873.2	777.6	682.8	590.0
Total cost/ unit	1435.7	1413.4	1390.6	1365.9	1250.9	1135.4	1022.8
Total costs	6.975	7.871	8.647	10.172	12.116	13.625	13.749
Profit	1.047	1.143	1.209	1.363	2.483	3.920	5.317

Overall reduction in unit cost 1979/84 same as in (1), i.e. 28.76%

Projections under proposed reductions in direct cost per unit, continued.

3) Direct cost/unit reduced by 12% over the three year period 1981/82, 1982/83, 1983/84.

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
Direct cost/ unit	894.2	887.7	880.9	873.2	760.3	751.1	741.7
Total cost/ unit	1435.7	1413.4	1390.6	1365.9	1233.6	1203.7	1174.5
Total costs	6.975	7.871	8.647	10.172	11.949	14.444	15.789
Profit	1.047	1.143	1.209	1.363	2.650	3.101	3.277

Percentage reduction in total cost/unit 1978/84 is 18.2%

Table F.8

Impact on projected profit levels of proposed price reductions (under varying assumptions) for BOCAE, 1979-84

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
1) 30% reduction in direct cost/unit in 1981/82, price reduction of 10% in 1978/79, and further 10% in 1981/82							
Sales £M	8.022	8.112	8.870	10.381	11.679	14.036	15.253
Costs £M	6.975	7.871	8.647	10.172	10.442	12.601	13.749
PROFIT £M	1.047	0.241	0.223	0.209	1.237	1.435	1.504
Profit/Sales	13.1%	3.0%	2.5%	2.0%	10.6%	10.2%	9.9%
2) 30% reduction in direct cost/unit spread over the three years 1981/82, 1982/83, 1983/84; price reduction of 10% in 1978/79 and further 10% in 1981/82.							
Sales £M	8.022	8.112	8.870	10.381	11.679	14.036	15.253
Costs £M	6.975	7.871	8.647	10.172	12.116	13.625	13.749
PROFIT £M	1.047	0.241	0.223	0.209	-0.437	0.411	1.504
Profit/Sales	13.1%	3.0%	2.5%	2.0%	LOSS	2.9%	9.9%
3) 30% reduction in direct cost/unit over the three year period 1981/82 to 1983/84, price reduction of 10% in 1978/79							
Sales £M	8.022	8.112	8.870	10.381	12.139	15.791	17.159
Costs £M	As in (2) above						
PROFIT £M	1.047	0.241	0.223	0.209	1.023	2.166	1.906
Profit/Sales	13.1%	3.0%	2.5%	2.0%	7.8%	13.7%	11.1%

Impact on projected profit levels of proposed price reductions (under varying assumptions) Continued.

	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
4) 30% cost reduction over the three year period 1981/82 to 1983/84, price reduction of 12% in 1981/82							
Sales £M	8.022	9.014	9.856	11.535	12.847	15.440	16.778
Costs £M	As in (2) above						
PROFIT £M	1.047	1.143	1.209	1.363	0.731	1.815	3.029
Profit/Sales	13.1%	12.7%	12.3%	11.8%	5.7%	11.8%	18.0%
5) 12% reduction in direct cost per unit over 1981/82 – 1983/84 and 8% reduction in price in 1981/82							
Sales £M	8.022	9.014	9.856	11.535	13.431	16.141	17.541
Costs £M	6.975	7.871	8.647	10.172	11.949	14.444	15.789
PROFIT £M	1.047	1.143	1.209	1.363	1.482	1.697	1.752
Profit/Sales	13.1%	12.7%	12.3%	11.8%	11.0%	10.5%	10.0%

3) Comparison of the unit cost reduction required to achieve specified strategic aims with that planned by the company in strategic plans for 1979/84.

3.1 Summary of previous results.

The following points have been made:

a) Comparison between unit costs of Boc Arc Equipment and another company with twice the annual output volume shows that by 1977/78 Boc are already at a disadvantage with unit cost 20% higher than the competitors, (Table F.3)

If the other company is growing at the same rate or slightly higher than Boc Arc Equipment, in terms of output volume, then the estimated cost reduction required by Boc is as follows:

11-13% reduction in unit cost is required over the period 1979/84 to maintain current differentials.

30-34% reduction is required in order to match unit costs of competitor by 1984. (Table F.4)

b) If the other company has four times the annual output volume of Boc Arc Equipment, then unit cost reduction required by Boc to maintain current differentials of 29% excess on unit cost by 1984 is again 11-13%.

The reduction required to match competitors costs by 1984 is 42-48%. (table F.4)

c) If the other company is currently growing at a much faster rate than Boc Arc Equipment in terms of output volume, then unit cost reduction required to maintain current cost differentials is 16-17%, and to match competitors costs by 1984 could be as high as 48%. (Table F.4)

d) Current strategic plans made by Boc Arc Equipment involve a high volume growth of approximately 18% p.a. c.g.rate over the next five years, and a large reduction in the direct cost of manufacture over most of their mainline products.
It is aimed to reduce direct cost per unit in the majority of products by 30%, to be implemented 1981/82 to 1983/84.
They plan to increase volumes by reducing the price in anticipation of the reduction in direct costs.

e) The effect of the proposed high volumes is that, under projection from the experience curve model, without the additional planned reduction in direct cost per unit, total unit costs should decline by 11% over the period 1978/84.
Projected profit levels are high although declining as a percentage of sales, since unit cost is declining at a slower rate than average price. (Table F.6)

f) If the proposed reduction of 30% in direct cost per unit is achieved by the end of the planning period, the reduction in total cost per unit will be 29% approximately. (Table F.7)

g) If the proposed reduction of 30% is only achieved in certain products so that, overall, a reduction of 12% is achieved in average direct cost per unit, then reduction in total cost per unit over the planning period will be 18% approximately. (Table F.7)

h) The effect of price reductions and direct cost reduction on the profit margin varies according to when each is introduced. (See Table F.8)
It is probably more feasible that the 30% direct cost reduction will be spread over the three years 1981/82 to 1983/84. In which case an immediate price reduction of 10% gives recovery in profit margins by 1982/83. Leaving the price reduction until 1981/82 is clearly

safer with regard to profit margins, but would lose the advantage for attempts to increase volumes of sales before that time.

3.2. Conclusions

If the company can achieve the 30% reduction in direct cost per unit, then the effect on projected unit costs happens in two ways.

Firstly, if the reduction can be used to reduce the average price and achieve large increases in volumes of sales, the reduction in unit cost 1978/84 projected using the experience curve model is approximately 11%. This is sufficient to maintain current cost differentials with a competitor currently producing twice the annual output volume of Boc Arc Equipment.

Secondly, the reduction in direct cost per unit will be in addition to the savings projected using the model, and this will add to the general reduction to produce an overall decline of 30% in total unit cost over the planning period. This is sufficient to match the unit cost of a competitor with twice the volume of output as Boc Arc Equipment, by 1984.

In the worst case, if the other company has four times the annual volume of output of Boc Arc Equipment, with a current growth rate of 20% p.a., then cost reduction of 17% is required for Boc to maintain the current differential, and 48% to match their unit cost by 1984. However, if Boc can achieve a unit cost reduction of 30% over the planning period, this will contribute towards regaining a competitive cost position. In the worse case, if they only achieve 18% reduction, this will at least maintain the current differential.

However, it must be strongly noted that the plan hinges on achieving high volumes of sales, with average compound growth rate of 18% p.a. over the period 1977-84. No study has been made of whether the proposed 10-20% price reductions are likely to result in volume growth of these dimensions.

APPENDIX G Reports to BOC AE during Stages I and II of the project.

INDEX

APPENDIX G

Reports to BOC AE during stages I and II of the project

The first report (Appendix G.1) was issued in April 1978. It reviews the results from testing experience curve models on BOC AE data and on BEAMA data for the UK industry, including the adverse trends between unit cost and average price of a BOC AE rectifier. (Chapter Five, details in Appendix C). It also includes results from a part of the investigation into reasons for these trends. (Chapter Seven, details in Appendix E, E.1-E.7) The remaining part of this work investigating any increase in complexity of the product, was instigated in response to comments from BOC AE managers after reading the initial report. (Chapter Seven, 7.2.3, and Appendix E.8).

Detailed results from most of the analyses carried out in this section of the research were included as a review of trends in the business (Appendix II of Appendix G.1). NB. Appendix I contained details of data etc, and is not included here as it would be a duplication of the relevant sections in Appendix C. (C.2.1 and C.3.2)

After a summary of results and conclusions, the report also offers eight alternative directions for continuation of the project after April 1978 (Page 397). These were expanded in an accompanying paper (Appendix G.2).

Both reports (Appendices G.1 and G.2)were presented at the BOC AE Management Meeting on 8th June 1978. Discussion mainly concerned further research into the validity of the experience curve model for BOC AE, with agreed actions as follows: (Extracted from the official minutes of the meeting).

i) Pat Thornley to talk to all board members in detail about the report and its implications.

ii) In the absence of competitive cost data, use to be made of Airco, Socomé and CIG (BOC or BOC related arc welding equipment companies in USA, France and Australia, respectively) for comparative cost information if possible. (General Manager to obtain data where available).

iii) Use to be made of official French and German price data to verify the price experience curve in the UK.

iv) Pat Thornley to pursue the implications of a time-related model for unit cost, rather than one based on cumulative output.

v) Pat Thornley's report to be incorporated into the next strategy review document.

vi) The future direction that Pat Thornley's project will take to be discussed at the August board meeting.

As a result of talking to board members individually, a second paper was prepared on proposals for future work in the project. (Appendix G.3). These covered further work on the experience curve, looking into alternative models, and a scheme to set targets for unit cost reduction and construct a strategic plan for achieving these targets. (G.3.3).

This paper was discussed at the meeting held on 2nd August 1978, at which the following points were made. It was felt that the amount of work proposed in G.3.3 could not be completed in the time available, and that verification of the experience curve hypothesis and the position of BOC AE on the curve was needed before any further work could begin. The BOC AE managers also felt that 'the operational cost reduction programs were felt to be a problem to a non-functional person'.

It was decided that the project should continue with work on validation of the model/investigation of alternative models, and then tackle part of the proposals in G.3.3, although this direction for future work should still remain flexible.

In the event, completion of research into alternative models coincided with the need to review the final direction of the project, with respect to changing priorities in the company. The report on results, from this part of the work, (Appendix G.4) also contained a list of options for future work in BOC AE arising from the results of stages I and II. Discussions with managers at BOC AE, and the decision on work which would form stage III of the project, are reported in Chapter Eight of the thesis. (Management reports in Appendices I and L).

Report on investigation into the existence of an experience curve model for prices and costs of manufacture of Arc Welding Equipment rectifiers

SUMMARY

1) Prices of arc welding rectifiers in the industry are on an experience curve of slope 81%.

2) Prices of arc welding rectifiers in BOC Arc Equipment are on an experience curve of slope 83%.

3) Total product cost per unit of production within BOC Arc Equipment is on an experience curve of slope 86.5%.

4) As a result of (2) and (3), the profit margin per unit is decreasing at 5% p.a. compound rate.

5) It is doubtful whether direct costs per unit for rectifier production as a whole in BOC Arc Equipment benefit from cost reduction due to accumulated experience.

6) The cost per unit of production of MIG, however, has shown effective reductions due to product design, resulting in an 80% experience curve for direct costs.

7) Expansion of the production unit has resulted in the growth of fixed costs which has been higher than growth in volume of output.

8) Factors found to constitute to the lack of cost reduction are:

a) Design specification of TIG machines

b) The trend away from production in the light end of the range(under 200A) and towards production in the heavier end (over 400A)

9) The lack of reduction in direct costs per unit plus the increase in fixed costs per unit of production, indicate the need to examine the area of production efficiency.

CONCLUSIONS

1) The difference in slopes between the experience curves for price for BOC Arc Equipment and the industry as a whole is probably due to a combination of trends in BOC Arc Equipment:

i) A trend towards production of the heavier type of machine

ii) A tendency for higher price increases, relative to the industry average, particularly over the last few years (see Appendix II).

2) The difference between the slopes of the experience curves for price and cost per unit for BOC Arc Equipment lead to the alternative hypothesis:

i) All companies in the industry are on the same slope cost curve as BOC Arc Equipment; in which case all are suffering similar or greater squeezes on profit margins per unit.

ii) There is a steeper product cost curve attained by other firms, and potentially attainable by BOC Arc Equipment.

At present no evidence is available for the selection of either hypothesis.

3) The evidence suggests that the experience curve may not be the best model for the direct cost per unit of production in this industry.

However, the 80% experience curve attained by total unit product cost of MIG sets demonstrates that such cost reduction is possible through product design.

4) The present policy towards TIG design contributes to the situation where there is a lack of cost reduction per unit.

The advantages of the design of TIG for greater sophistication and technological advance are clearly those of marketing a superior TIG process, and the maintenance of prestige and company image. This has obviously contributed to the steady sales and growth rate of the TIG product (see Appendix II).

However, the resultant increases in cost per unit of production are a major contributory factor to the gradual erosion of profit margins.

5) Although data has not been available for a study of the elements of production cost, the indirect evidence of the overall increase both in direct and fixed costs per unit at the centre of production suggests that this area must be a contributory factor to the lack of cost reduction, and would benefit from fuller examination.

Alternative directions for continuation of project after April 1978

Bearing in mind the dual purpose of the project, being to assist BOC Arc Equipment and have the academic content of a PhD Thesis, the following are a list of suggestions which may be considered for continuation of the project.

1) A model of total product costs, incorporating all manufacturing, marketing, establishment and R and D costs, to be used for prediction of future product cost with the facility for altering the input variable.

2) A Corporate Planning model for examination and evaluation of planning strategies and decisions with particular reference to market share objectives.

3) A more extensive corporate planning model including fuller input parameters such as volumes of output, competitive reaction, investment required, and predicting effects on profit, cash flow ROI etc.

4) Marketing strategy research to look into ways of achieving the present strategy.

5) Design of formal system for corporate planning information, for immediate use in planning purposes and for monitoring company performance against strategic plans.

6) Investigation and evaluation of the present basis for strategic planning and comparison with other methods and conceptual bases.

7) Evaluation of cost-reduction opportunities in the company, in the fields of manufacturing, marketing, administration etc, plus the interaction of any schemes with the marketing potential of the product.

8) An investigation of the parts played by component strategic plans of departments/cost centres of the company in the overall strategic plan, and the effects of any divergence between the two.

Report of investigations into the existence of an experience curve model for prices and costs of the manufacture of Arc Welding Equipment rectifiers

I Introduction

1) BOC Arc Equipment consider that their main product is the welding rectifier. Consequently, this investigation has taken the manufacture and marketing of rectifiers to be the definition of the business, with the rectifier as the unit of output.

2) As a result of (1) the Manual equipment part of the business has not been investigated with regard to costs, as manual equipment is AC. It is also mainly factored and so will not contribute to production experience.

3) The manufacture and marketing of welding rectifiers has been the joint concern of HWR Ramsgate, and BOC Arc Equipment since the early days of rectifier production in 1952-53. This situation has existed even if the two companies were separate (pre-1965) financially linked (BOC holding 66% shares in HWR from 1965 to 1972) or amalgamated into one business (1972 onwards).

Therefore, in this context, the business unit is defined to be HWR and BOC Arc Equipment, treated as a whole.

For details of amalgamation of the data, see Appendix I.
(now in Appendix C, 3.2.4)

This data will be referred to as total business data.

4) Sales and cost data for rectifiers alone has been impossible to isolate and so the following inconsistency in the data must be considered when interpreting results:

i) Value of sales and costs refers to total MIG, TIG and Plasma equipment. (Data source, A-11's)

ii) Volume of rectifiers produced refers to rectifiers alone. (Data source, production records).

5) Available data covers the period September 1965 to September 1977.

6) The deflating index used throughout is that of the wholesale price index for home sales of all manufactured products. This has been found to correlate well with sales of welding equipment.

All trends reported are thus strictly relative to this index.

7) Throughout the report, the term experience curve slope, or experience curve with slope ...., refers to the complement of the percentage reduction in costs with every doubling of experience, or cumulative output.

8) Details of all data are given in Appendix I. (Now in App. C.3.2)

$$\text{NB average price} = \frac{\text{Deflated value of sales for the year}}{\text{Volume of output}}$$

9) All information, trends, etc, not directly relevant to the experience curve investigation but considered worthy of note, have been collected and presented as a business analysis, in Appendix II.

II Results of primary investigation

1) Average price of a rectifier for the whole industry is on an experience curve with slope 81% (see graph no 1)

The data is obtained from BEAMA returns for all firms subscribing to BEAMA. Fluctuations in the curve are thought to reflect changes in the source of the data; ie in the number and type of the firms subscribing to BEAMA.

The model fits the data very well. (C=-.89)

2) Average price of a rectifier for the total (BOC +HWR) business is on an experience curve with slope 83% (see graph no 2)

The model fits fairly well (C= -.72), and is corroborated by BEAMA data for BOC Arc Equipment. The fluctuations in this curve correspond to time lags between sales and production. (See Appendix II). The lags produce a slightly higher or lower average price than would actually exist.

The result demonstrates that the total business average price follows an experience curve whose slope is almost the same as that of the industry. Reasons for the difference in slopes may be:

i) The product mix of the business relative to that of the industry has moved towards the more expensive end of the market.

ii) There has been a policy of price increases relative to the industry average price.

We note that the general trend of price rises between 1970 and 1973 follows the pattern of the underlying fixed plus direct unit cost curve. (Graph no 3)

3) Fixed + Direct cost per unit produced for the total business reveals an experience curve with slope 86.5% (see graph no 3)

We note the short term trends of increases in costs over the periods 1970-73, 1974-77.

However, the long term trends are the subject of this investigation; these will be analysed later. (section III)

The fit of the data to this model is not very good (C=-.61, not statistically significant). However, this is partly due to the vagaries in the data, described in the introduction, which cause some of the fluctuations.

4) The profit margin per unit (difference between sales per unit and fixed + direct costs per unit) for the total business shows an overall downwards trend (see graph no 4)

The profit margin as defined, is decreasing at 5.5% p.a. compound rate.

We note that the profit margin fell from 1966 to 1968, enjoyed an increase over the boom years 1969 to 1972, and has declined overall since that time, although slight increase occured in 1975.

These initial results suggest the alternative hypotheses:

i) Other firms have a similar product cost curve, and are suffering similar reductions in profit margins per unit to BOC Arc Equipment.

This alternative has not yet been pursued, due to difficulties with lack of data.

ii) Other firms have a steeper total product cost curve than BOC Arc Equipment. That is, BOC are not enjoying benefits of cost reductions experienced by other firms, and therefore presumably potentially available to BOC Arc Equipment.

This alternative clearly requires fuller analysis of the cost of manufacture of the product.

III <u>Analysis of fixed plus direct costs</u>

Available data of the fixed and direct costs of the total business facilitates two initial methods of analysis:

i) Fixed and direct costs analysed into those generated at HWR, and those at MK (MK covering all costs not incurred at HWR, irrespective of actual premises occupied).

ii) Analysis into fixed costs and direct costs, of the whole business.

1) <u>The analysis of costs between HWR and MK</u>

(see graph no 3)

The analysis of costs in this way, particularly direct costs, has a certain lack of validity due to internal changes in the circumstances which are reflected in the data, and may lead to false conclusions. For example, the transfer of production of wire feed units from MK to HWR in 1972/73 would be favourable to MK costs/unit and unfavourable to HWR.

However, an investigation of costs incurred by the seperate sites is thought to provide some insight into cost structure; but the contributory factor described above must be considered when interpreting results.

<u>Results</u>

a) Total product costs (fixed plus direct costs per unit) at HWR show a steady increase over the period, of 3.9% p.a. compound growth rate (see graph no3)

b) Total costs at MK show a pattern of large fluctuations, reflected in the pattern of costs for the whole business.

An experience curve model, although not fitting the data very well, shows an overall experience curve slope of 66.3%. It must be emphasised that a large element of this is attributable to transfer of production to the Ramsgate factory.

2) Fixed costs and direct costs of the whole business

a) Fixed costs per unit for the total business fit an experience curve model with slope 76.0% (see graph no5).

This result reflects the spreading of overheads over increasing volumes of production.

Fixed costs are dominated by those incurred at MK, which fit an experience curve model with slope 71%.

Those at HWR, however, have increased quite substantially over the period, resulting in the proportion of fixed costs per unit incurred at HWR increasing from 8% to the present 22 . Thus if the trends continue, fixed costs at HWR will become increasingly significant in the business.

b) Direct costs for the total business do not fit an experience curve model very well. In fact, if the first two points (1966 and 1967) are omitted, the trend is an increasing one. (see graph no6)

Direct costs are dominated by those incurred at HWR (65-70% of direct costs per unit in the last few years). These have increased at 3.7% p.a. compound growth rate over the period.

The fluctuations in costs per unit at HWR depend on fluctuations in production, rising and falling with production levels. This presumably reflects an increased awareness of costs when business is declining.

Direct costs at MK show the pattern of very large fluctuations with a trough in 1970, a peak in 1973, and a decline since then. (see graph no 6). The overall trend on an experience curve model is that of a fairly steep slope, but again no great emphasis should be placed on this, due to the limitations of the data already described.

Hence we obtain an overall view of fixed plus direct costs per unit.

	MK	% comp	HWR	% comp	TOTAL	
FIXED COSTS	Smoothly decreasing on 71% slope	45%	Smoothly inc. at 5.2%p.a. c.g. rate	15%	Smoothly decr. on 76% exp. curve (Dominated by MK)	40%
Percent composition	80%		20%			
DIRECT COSTS	Large fluctuations. Overall decr.	55%	Fairly smooth inc at 3.7%pa c.g. rate	85%	Fluctuation of MK data Overall 95% exp. curve	60%
Percent Composition	Decreasing 50-35%		Increasing 50-65%			
TOTAL FIXED PLUS DIRECT	Large fluctuation. Overall 66% exp. curve just dominated by direct costs		Smoothly inc. 3.9% p.a. c.g. rate		Overall trend 86.5% exp. curve. dominated by direct costs	
	Decreasing 50 - 40%		Increasing 40 - 50%			

CONCLUSIONS

Areas for fuller investigation must be:

i) The trend of direct costs per unit; which, although showing a slight decrease overall, does not appear to be showing cost reductions from the gaining of experience.

ii) The reasons for the large fluctuations in direct cost per unit at MK.

iii) The increase in fixed costs per unit at HWR.

IV Investigation of the three suspect areas

i) Direct cost per unit

The investigation has had to concentrate on the only data available, which concerns production costs at HWR.

The breakdown of these direct costs is 83% materials, 17% labour, in a fairly constant ratio.

On examination we find that both materials and labour costs per unit are responsible for the rise in direct costs; both are increasing at 3.7% p.a. compound growth rate. (See graph no 7)

Consideration of factors which may influence the cost of production per unit produce the following list.

1) Absolute cost of materials
2) Design of the product
3) Absolute labour rate per hour
4) Labour efficiency
5) Rate of output
6) Width of range of rectifiers in production
7) Product mix with respect to:
    a) Proportion of rectifiers, equipment and spares in the total product mix
    b) Proportions of MIG and TIG within the rectifier group
    c) Proportions of light and heavy types of rectifiers in the rectifier group
8) General production efficiency
9) Variations in the data with respect to the changes in proportion of production undertaken at MK

1) Absolute cost of materials

The three constituent materials in the manufacture of rectifiers investigated here are copper (38% of material costs), laminations (32%) and metals, bakilite (13%). Data on electrical parts (17%) was not readily available, and consumables form less than 1% of material costs.

See Appendix II for details.

With the overall decreases in copper prices over the period combined with skilful buying on the copper market, fairly constant cost of laminations, and slight increase in the price of steel sheet, we conclude that the absolute cost of materials relative to the deflatory index, has certainly not increased over the period, and has probably decreased.

Conclusion.

The absolute cost of raw materials is not responsible for the general increase in direct costs per unit.

2) Design of the product (see graph no 8)

Using data from BOC Arc Equipment alone, to analyse direct cost by process, ie into MIG, and TIG Plasma, we obtain the following results:

i) MIG has benefitted from design engineering, with the introduction of the SMR and Transmig ranges, resulting in direct costs per unit for the production of MIG equipment lying on an 82% experience curve.

From the limited amount of data available it does not appear that individual models benefit from cost reduction as a result of the accumulation of experience.

Conclusion

Overall cost reduction is achieved in production of MIG, through engineering design and not through production experience.

ii) TIG direct costs per unit reveal the origin of the extreme fluctuations reflected in the pattern of direct and MK costs.

The dynamics of TIG production reveal two elements of this pattern:

a) The trends in the curve follow corresponding swings toward the more expensive or cheaper ends of the range.

b) These trends are exaggerated by the greater suffering of TIG from the effects of extreme fluctuations in production, combined with smooth trends in sales and costs of sales. This results in average cost per unit following a four year cycle, with the overall trend of an 89% experience curve slope.

Conclusions

The policy towards the development of TIG rectifiers is that of achieving greater sophistication and technological advance, rather than cost reduction.

3) Absolute labour rate per hour

The trend in deflated labour rates per hour is that of a very slight decrease over the period.

Conclusion

Labour rate cannot be blamed for the lack of cost reduction.

4) Labour efficiency

The only measure of labour efficiency from available data is on the output per worker, ie sales value divided by the number of workers. This rises to a peak in 1971/72 and declines from that time onwards, to arrive at 1968/69 levels in 1976/77.

This measure is, however, not very representative of efficiency, as the tendency when production levels are low is to engage workers in other tasks, and not to lay them off.

Insufficient evidence upon which to draw a conclusion.

5) Rate of Output

This does show some correlation with costs per unit, particularly when costs are separated into those for MIG and TIG. There are clearly several reasons for this:

i) Length of each production run
ii) Compatability of the level of production with plant layout and tool availability
iii) Attitude to cost control

Conclusion

The rate of output could be a contributory factor.

6) Width of range of rectifiers in production

Neither the width of the range in general, nor the numbers of new models being introduced, or old models being eliminated, seem to correlate with costs per unit.

Conclusion

The width of range does not affect direct costs per unit.

7) Product mix

i) Proportions of rectifiers, equipment, and spares in the product mix. The proportion of rectifiers in this mix does not correlate with price or costs per unit.

ii) Proportion by process - MIG and TIG.

The proportion of MIG in production has increased slightly from 59% to 68% and in sales from 45% to 50%. The effects of this on average direct cost per unit would be an overall decrease (as MIG sets cost less than TIG on average) and hence does not explain the lack of cost reduction.

iii) Proportions of light and heavy machines in production.

The percentage of machines in the category of 200 amps and over has increased at 5.4% p.a. compound growth rate.

There is some correlation (c = .69) between the percentage of heavy machines in the mix and direct costs per unit, but this relationship does not explain all the increase in cost per unit of production, nor the discrepancy between price reduction rate and cost reduction rate.

<u>Conclusion</u>

The slight swing towards machines over 400 amps may be a factor in the lack of cost reduction.

8) <u>Production Efficiency</u>

The scarcity of data has not enabled an investigation of production efficiency, but this area could possibly be the subject of fuller qualitative examination or a future monitoring system.

Factors which may be considered:

a) Availability of materials or component parts
b) Availability of experienced manpower
c) Relative priority attached to a given model
d) Efficiency of operating controls
e) Frequency of schedule changes, and degree of pressure attached to the programme
f) Whether plant layout is favourable to production of particular models
g) Availability of specialised higher production machinery
h) Implementation of design charges

9) i) <u>Variations in proportion of production at HWR</u>

There is some evidence to show that production at HWR contains an increasing proportion of non-rectifier equipment, such as wire feed units, System 3, and manual AC transformers.

This will have the effect of an apparent increase in costs at HWR. However, any change in this proportion of the product mix is internal, and will not affect the overall direct costs per unit.

ii) <u>Large fluctuations in direct costs per unit at MK</u>

This appears to depend on the large fluctuation in costs per unit of TIG production, which has already been discussed.

iii) <u>Fixed costs per unit at HWR</u>

Fixed costs per unit at HWR have grown at 5.2% p.a. compound growth rate.

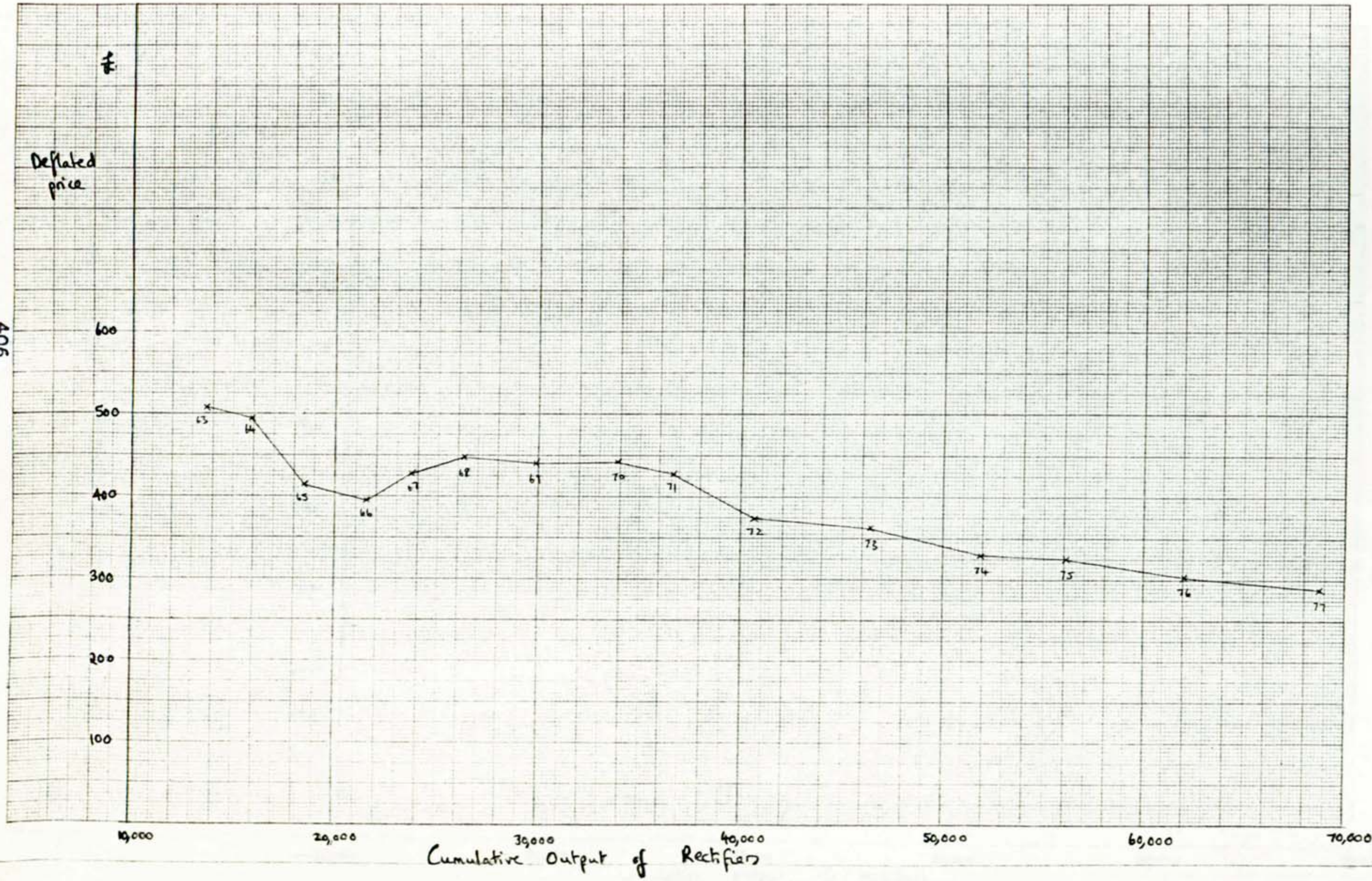
The greatest growth has taken place in administrative costs, with salaries, pensions and maintenance of office equipment having the highest growth rates.

The expansion of the business in general is reflected in the growth of the value of total fixed assets for the business. (13% p.a. compound growth rate).

This has resulted in a growth of establishment costs per unit (rent rates, plant and building maintenance, fuel etc.) and the need for the introduction of security services, computer facilities, etc.

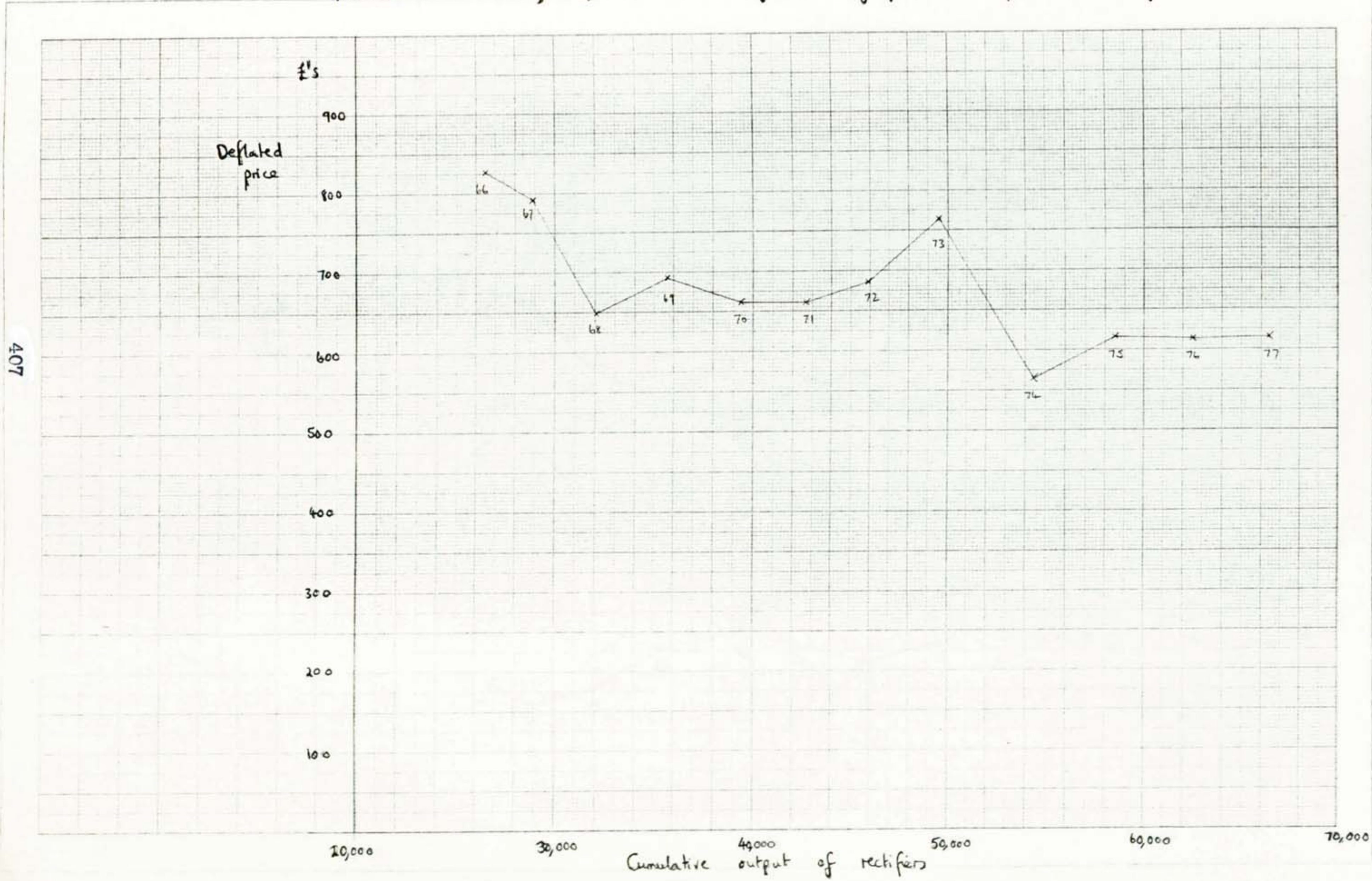
However, this general expansion and resulting growth in fixed costs has not been matched by growth in output volumes and so has resulted in increased fixed costs per unit.

Total Industry rectifier sales : deflated average price on experience curve with 81.1% slope. Graph G.1

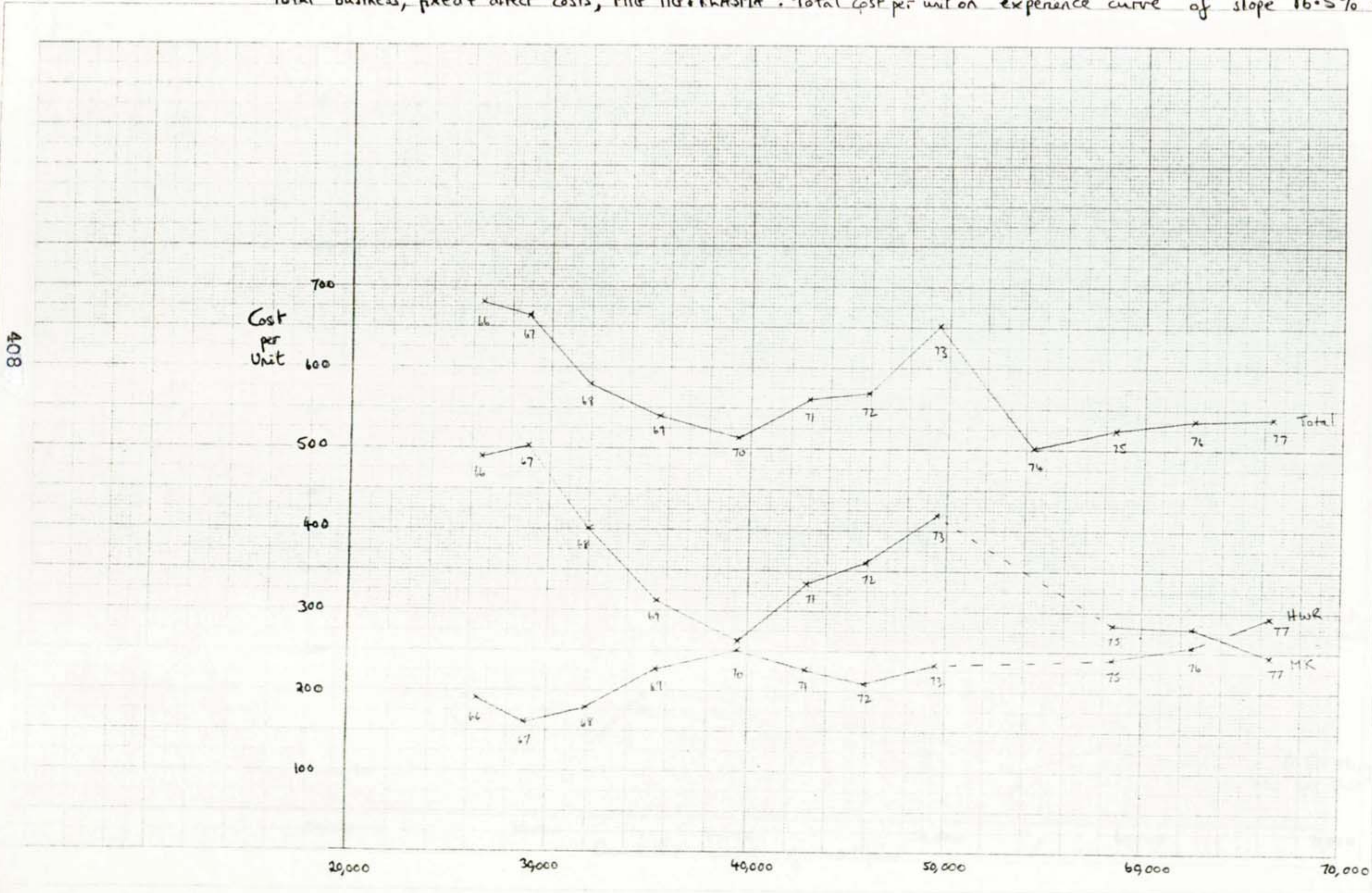


Graph G.2

BOC AE Total business, MIG, TIG & PLASMA : deflated average price on experience curve of 83.02% slope

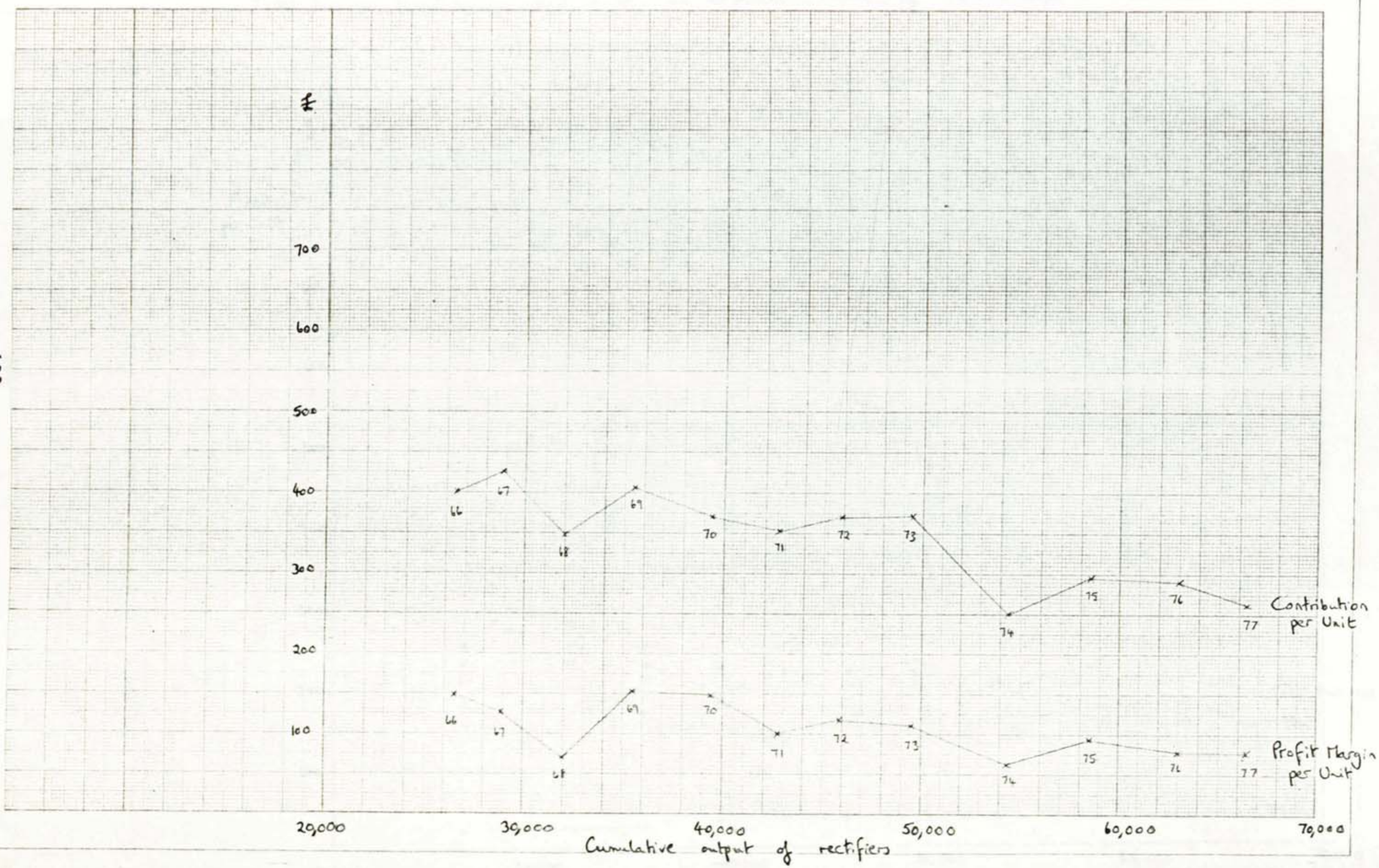


Total business, fixed + direct costs, MIG TIG + PLASMA : total cost per unit on experience curve of slope 86·5% G.3



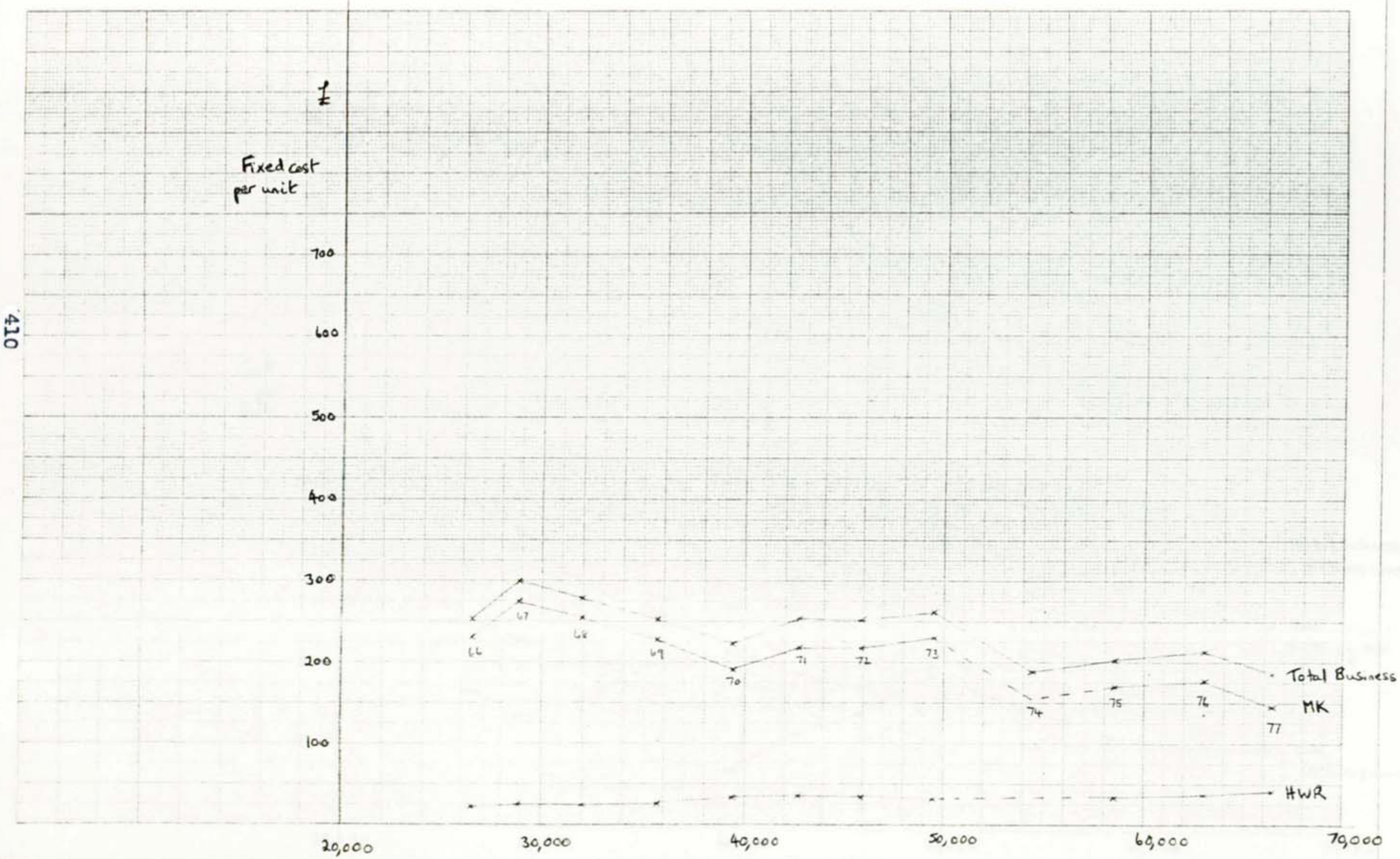
Contribution and profit margin per unit are declining (1966-77)

Graph G.4



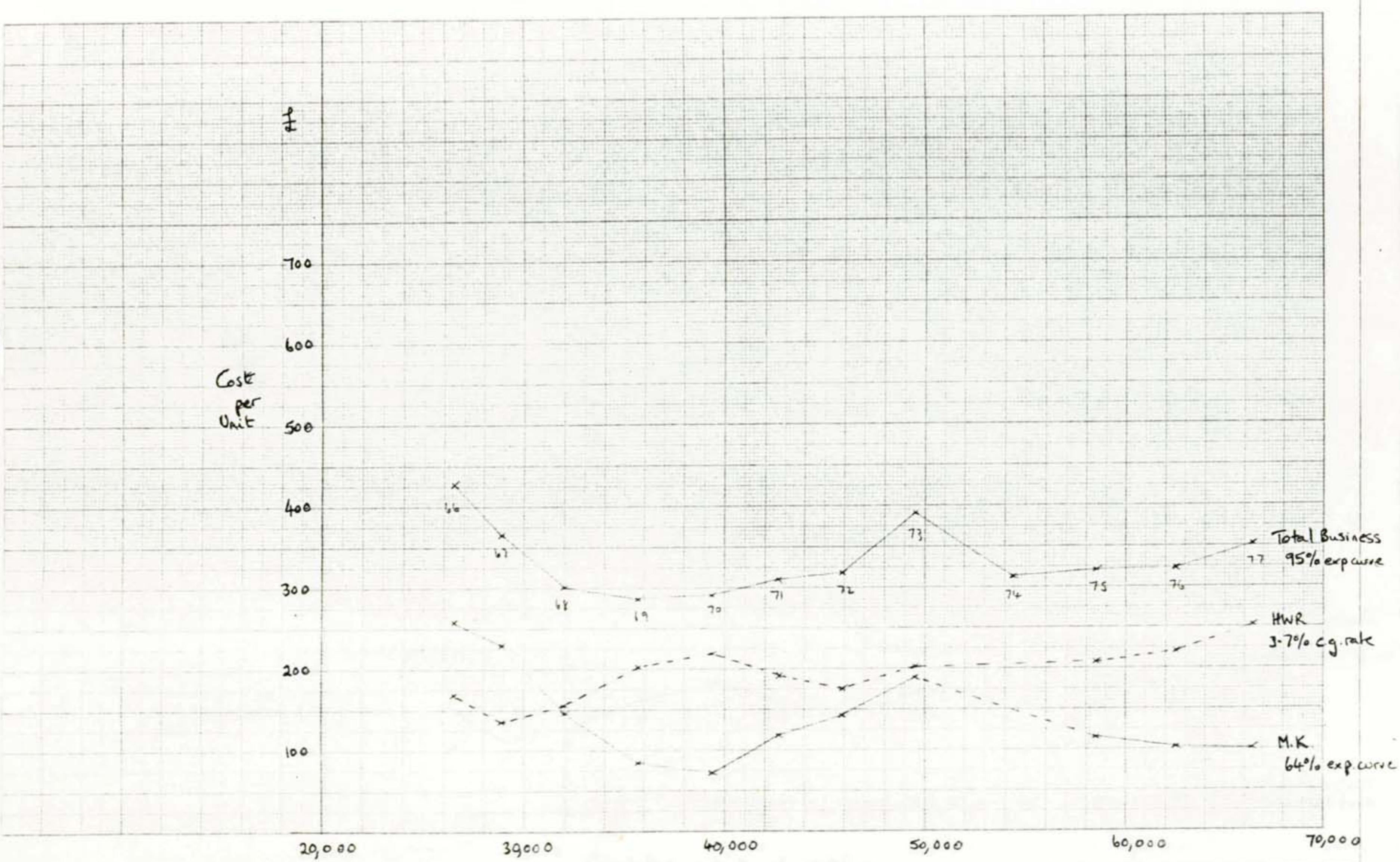
Graph G.5

Total business fixed cost per unit is on an experience curve of 76.7% slope



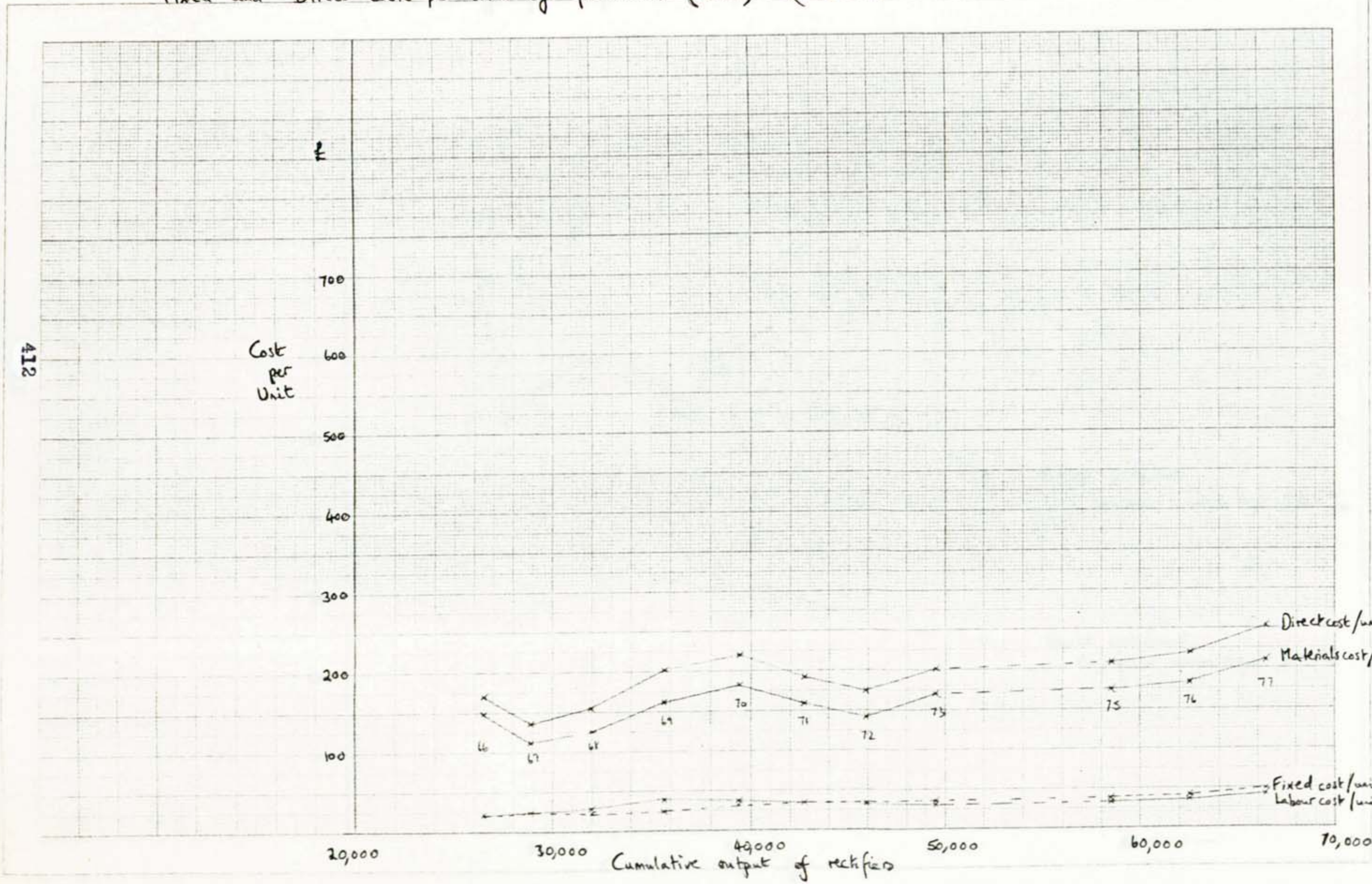
Graph G.6

Total business direct cost per unit: declined 1966-68 but overall increase 1968-77



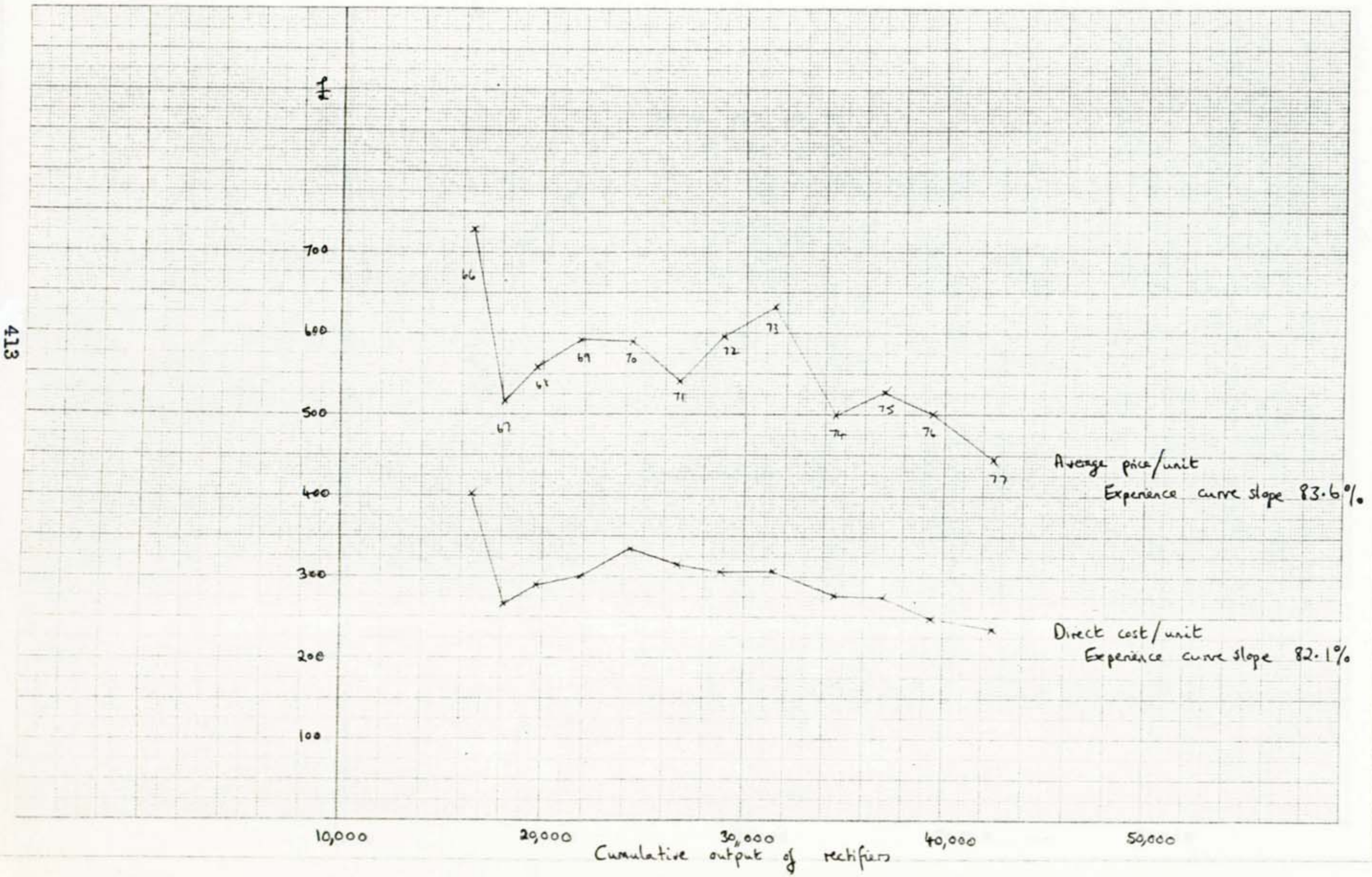
Graph G.7

Fixed and Direct costs per unit of production (HWR) (1966-77)



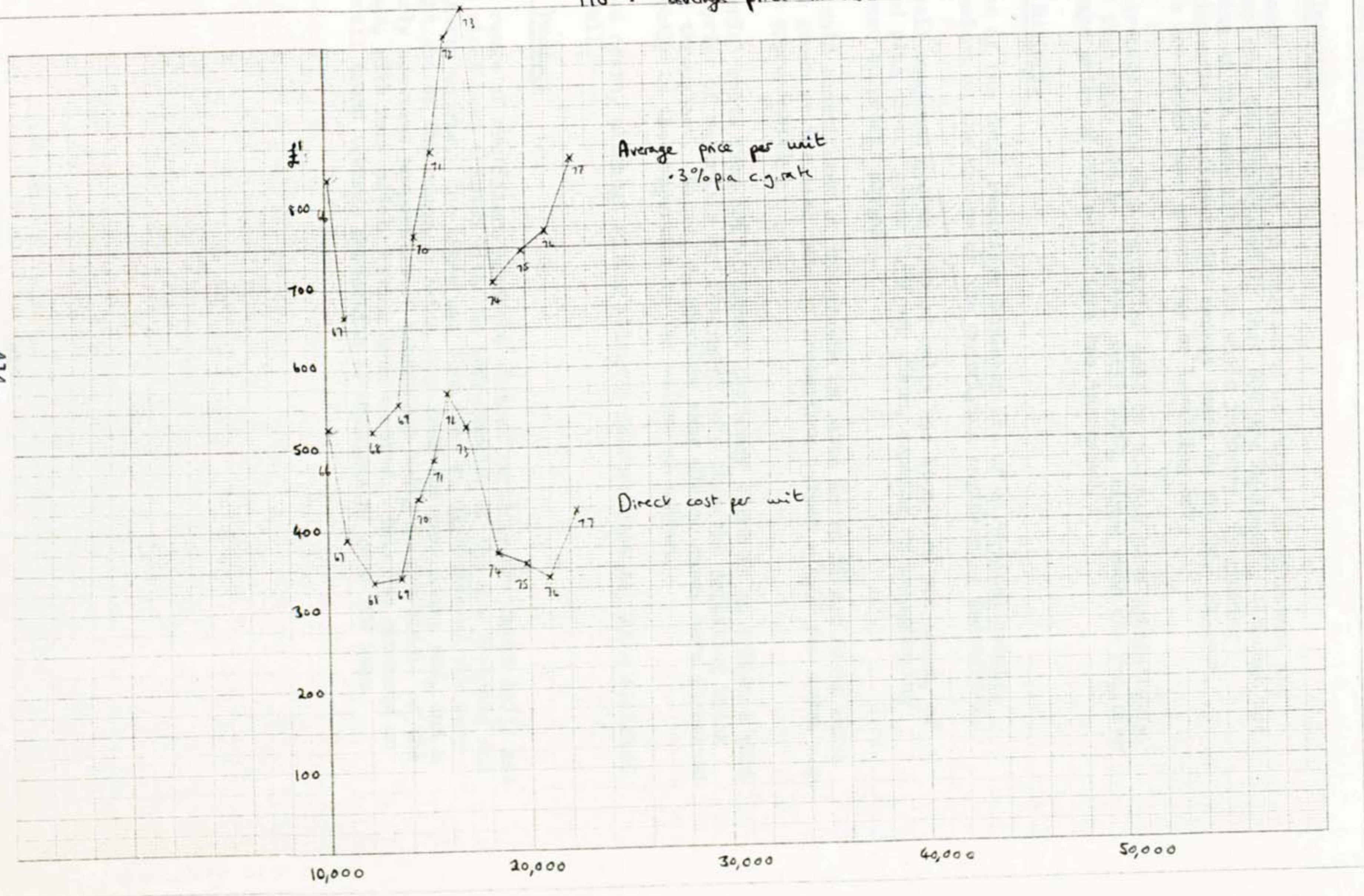
MIG: average price follows unit cost on overall decline 1966-77

Graph G. 8a



Graph G.8b

TIG : average price increases while unit cost decreases 1966-77



II BUSINESS ANALYSIS

Summary and Conclusions

1. The Industry

Although the data must be considered as rather inconsistent and incomplete, the impression is that BOC Arc Equipment, although not growing at the same rate as the whole industry, is growing sufficiently to maintain its market share in the UK. However, there are signs that growth may be levelling off.

The average price of a rectifier sold by BOC has been consistently less than that sold by industry until 1975, since when the relative average price of BOC rectifiers has increased.

2. The Business

Sales of the total rectifier business are of a cyclical nature, dependent on the cycles of the underlying engineering industries.

Overall compound growth rate of sales has been 2.6% per annum, of fixed plus direct costs 3.3% per annum, causing an accompanying squeeze on profit margins.

The main constituent of the growth in costs is in direct costs which have grown at the same rate as production output - 4.7% per annum c.g. rate approximately.

Material costs from 80% of direct costs and there is no evidence that the price of materials has increased more than the deflating index used throughout. Hence, we conclude that direct costs have increased directly in the proportion to the volume of output.

Fixed costs, although rising slightly in boom periods, have declined overall.

3. The Product

The range of rectifiers produced widened considerably until 1973, and has since been trimmed with the introduction of the new Transmig and Transtig models. The trend has been that of expansion of the very light end of the range, a swing away from the very heavy end, and a fairly constant proportion of production being in the middle of the range, with many models having been uprated. This has produced an overall trend towards production of machines of over 200 amp.

MIG

MIG is the part of the business whose sales are dependent on the cyclical nature of the business of those investing in the equipment, i.e. investment in MIG takes place when times are good.

Thus MIG sales will be more dependent on marketing and design than TIG, which has a steady pattern of sales.

A fairly new product in 1966, MIG has enjoyed a production output growth rate of 6% p.a. c.g. rate. Sales, however, although growing at a comparative rate until 1973, have declined since then, producing an overall average growth rate of only 3.7 % p.a.

Analysis reveals two possible factors contributing to this decline : firstly, the decline of the S.M.R. range which reached its peak in 1973 ; secondly, that prices of MIG rectifiers have increased since 1972, with particularly sharp increases in the last few years (according to BEAMA data). We conclude that the introduction of the new Transmig range in 1976 has yet to provide an impetus to sales, but could still do so. The policy on prices should perhaps be examined.

Cost of manufacture of MIG equipment has decreased, due to the benefits of design engineering, and not to production experience.

TIG and PLASMA

TIG and PLASMA show a smooth pattern of sales, with average compound growth rate of 6% p.a., to become an increasing proportion of the rectifier business. (40% in 1977).

Thus, the sales of TIG seem to be assured and development has been along the lines of increased sophistication, with allied increases in cost of manufacture.

Prices of TIG equipment do seem to have been increased since 1975 to allow for the increased costs inherent in the new Transtig range, but these increases do not appear to have been at the expense of sales.

OEM/AUTOMATICS

Sales to other equipment manufacturers have declined over the total period, but have shown a steady increase since 1974. Since production outputs of automatics have grown at 3.4% p.e. c.g. rate, this indicates that the MIG and TIG elements of OEM sales must have suffered a decline.

ANALYSIS

1. AC Manual Equipment

Sales of AC Manual Equipment, when deflated, show a decline of 5.6% p.a. compound rate. Once 35% of the business, it now forms 18% of sales. However, this is not a very profitable sector of the business since 18% of sales gives only 10% of the contribution.

Since the equipment is AC, and all factored, we omit data on MANUAL equipment from our data for the combined rectifier business of HWR and BOC, which is the subject of this analysis. However, it is noted that this sector forms 18% of sales and may benefit from analysis and examination of reasons for its decline.

2. Electrodes

The manufacture of electrodes was transferred to Waltham Cross in 1969. The data for the years 1965/66 to 1968/69 has been omitted from total business data.

3. Total Rectifier Business

Here we treat HWR and BOC Arc Equipment as a joint business throughout the period 1965/66 to 1976/77. For details of merging relevant data, see Appendix I.

The business is the manufacture and marketing of welding rectifiers, and so we include data pertaining to MIG, TIG, PLASMA, DC MANUAL and AUTOMATICS as being relevant to our business unit.

A. Market Dynamics

a) The Arc Welding Industry (see Graph 1A) (G.9)

The only data available on the total industry of arc welding equipment manufacturers is that supplied to BEAMA by its subscribing members (see Appendix 1 for details).

From the category of rectifier sales we obtain a growth rate for the industry of 5.7% p.a. for value of sales. However, this apparent growth rate includes the factor that an increasing number of firms send data to BEAMA ; and excludes the growing number of small manufacturers and importers of welding equipment who do not subscribe to BEAMA.

b) Total Business Sales (BOC Arc Equipment + HWR)(see Graph 2A) (G-10)

Accounts data for total equipment sales show an average compound growth rate for the business of 2.63% p.a.

Data from BEAMA for BOC Arc Equipment sales of rectifiers alone give a compound growth rate of 6.8% p.a. However, this data excludes sales to other equipment manufacturers, and a lot of export sales which consist of specials.

The general pattern of sales from BEAMA data and accounts data for BOC, coincide, and both show the same phenomenon of peaks in sales occurring a year before the peaks of sales for the whole industry.

c) Market Share

From the data supplied to BEAMA, BOC Arc Equipment appear to have a market share which is growing at 1.4% p.a. c.g. rate, and averages 42.5% over the period 1966 to 1977.

d) Prices (Graph 3A - G.11)

From the BEAMA data, the average price of recifiers sold by BOC is less than that of Industry, until 1975, match those of Industry from 1975 to 1976, and then take a sharp increase over Industry in 1977. An analysis of the limited amount of data on MIG and TIG separately show :

(i) BOC MIG prices show an overall increase from 1972 to 1977 with particularly sharp increases in 1975 and 1977 ;

(ii) BOC TIG prices fall until 1975 followed by a sharp increase in 1976, falling again in 1977.

Industry MIG and TIG prices fall steadily over this period.

This reflects a reported general policy of BOC Arc Equipment from 1975 onwards to increase prices to the maximum allowed by the market.

B. Business Dynamics (Total rectifier business, BOC Arc Equipment + HWR)(See Graph 2A)

NB. The overall average compound growth rate p.a. for the period 1966 to 1977 is 2.63% p.a.

Total Sales seem to follow a four year cycle of one peak year followed by three years of decline, peaks occurring in 1969, 1973, and possibly 1977. It is worth noting that if sales in 1977 do represent a peak of the present cycle, that peak is not so high as the 1973 one, indicating a possible levelling off of growth.

MIG Sales, 45% of total rectifier business sales in the early years, reach peaks in 1970 and 1973, but have shown an overall decline since 1973. Having reached a peak of 61% of sales in 1970, MIG now holds 50% total business rectifier sales.

Overall average compound growth rate of MIG is 3.7% p.a.

TIG and PLASMA Sales steadily increase over the period, rising from 32% of sales to 40% in 1977, giving an overall compound growth rate of 6% p.a.

Sales to other equipment manufacturers have declined over the total period, but have shown a steady increase since 1974.

At present the product mix by value is approximately 50% MIG, 40% TIG and PLASMA, 10% OEM.

b) Underlying Trends (see Graph 4A) (G.12)

The peaks and troughs of total sales, and MIG sales in particular, appear to coincide with those of the underlying mechanical engineering Industry (total sales correlate well with orders on hand, total market for mechanical engineering Industry).

TIG sales, however, are very smooth, and not correlated with peaks and troughs of the underlying industry, indicating that purchases of TIG are not dependent on cyclical variations in the market.

c) Volume of Output (see Graph 5A) (G.13)

NB. Figures for volumes refer to rectifiers only.

Production is again of a cyclical nature, of 4-5 years in length, with peaks occurring in 1970 and 1974.

Analysis

1. By process (see Graph 6A) (G.14)

The higher growth rate in production output has occurred in MIG (6.2% p.a. c.g. rate over the period).

The proportion of MIG by volume increased from an initial 58% to a peak of 72% in 1970, then declining slightly to the present 69%

TIG and Automatic volumes produced have each grown at approximately 3.5% p.a. c.g. rate.

(ii) By output size (see Graph 7A) (G.15)

In the early years production is dominated by two main size ranges : the 151 to 200 amp range (the MRCS 200B) and the heavy range of over 350 amps, (mostly TIG and AUTOMATICS).

The trend from 1969 onwards is for expansion in the very light range ; a swing away from the production of heavy sets ; and an uprating of sets in the middle ranges to produce a swing away from the 151 to 200 amp to the 200 to 350 amp ranges, i.e. production in the total 151 to 350 amp range remains fairly steady.

d) Stock (see Graph 8A) (G.16)

Total stock figures are those for production and finished goods stock for MK and HWR.

It is evident that considerable stock-building has taken place, with peak stock levels occurring in 1974 and 1976.

HWR The main bulk of this stock building has taken place at HWR, reaching a peak in 1976. Stock figures comprise approximately 66% materials, 33% WIP, this proportion remaining fairly constant. Initially the levels of stock followed the cyclical nature of the trade, but from 1972 onwards, stock-building has taken place at an average compound growth rate of 30% p.a., reaching a peak of 58% of sales in 1976. These levels, however, are now being decreased. The main reason for stock-building has been for strategic purposes, to prepare for growth of the business.

MK Stock at MK reaches a peak in 1974, and finished goods stock in particular has shown a considerable decrease in 1976-1977.

e) Costs (see Graph 9A) (G.17)

Total fixed and direct costs tend to follow the pattern of total sales, although as direct costs are dependent on production output, the effects of this are apparent where peaks in sales and production do not correspond.

1. Fixed and Direct Costs

Overall average growth rate over the period is 3.286% p.a. These have risen as a percentage of sales from 78% in 1966 to 88% in 1976 and 1977, having risen to 89% in 1968 and 1974.

This indicates that profit margins fell proportionately, although have risen slightly since 1974.

2. Fixed Costs

Fixed costs for the total business rose during the boom years of 1969-70 and 1973-4, but have now fallen almost to 1966 levels, overall average growth rate being 1.4% p.a.

This reflects the need for higher fixed costs to cope with higher levels of sales and production, with a successful amount of cost reduction over the last few years.

3. Direct Cost

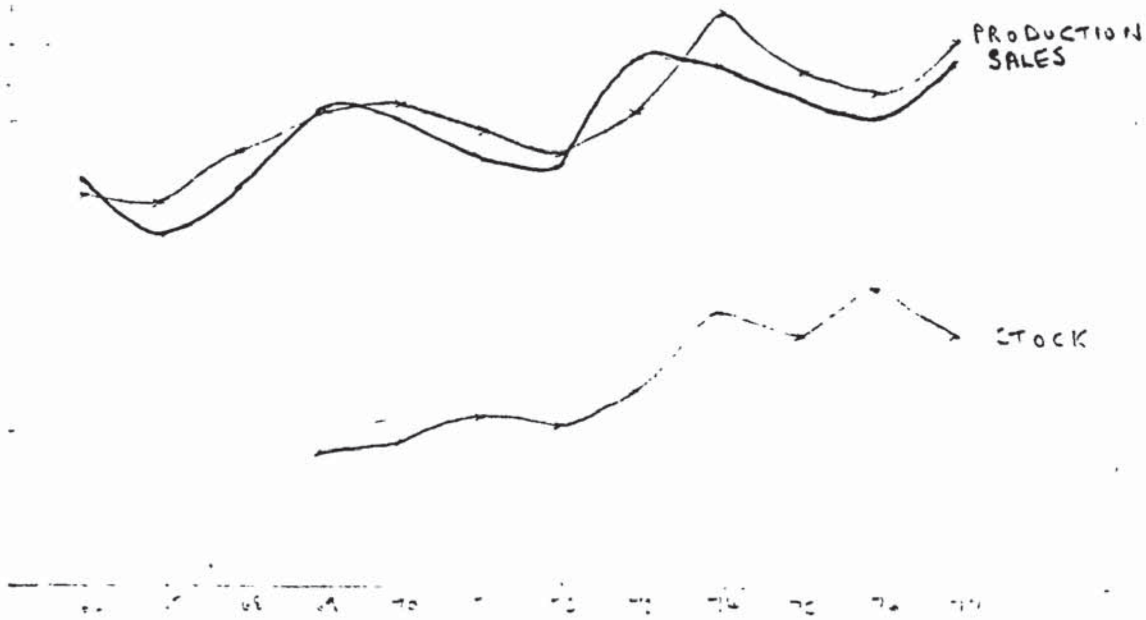
These have risen as a proportion of sales from 45% to 55% approximately over the period, again indicating a squeeze on contribution levels.

Overall average growth rate in total direct costs is 4.69% p.a. Further analysis of costs occur in the main report. Thus it is certainly the direct costs which are causing the decreasing profit margins.

SUMMARY - DYNAMICS OF TOTAL BUSINESS

1. Sales of arc welding equipment coincide with the peaks and troughs of engineering industry orders on hand, i.e. investment in welding equipment occurs in the production-planning stage, when the order book is full. This trend applies, however, mainly to MIG, with investment in TIG being independent of fluctuations in orders.

2. Production A peak in production occurs in the year following a peak in sales, but the troughs coincide, i.e. once sales start increasing, production increases instantaneously ; however, production continues increasing after sales have started dropping off again.



3. Stock With the above model, stock should reach a trough in 1969, a peak between 1970 and 1972, a trough in 1973, and a peak between 1974 and 1976.

The data fits this pattern fairly well until 1975, bearing in mind the anomalies of the data :

i) The underlying increases in stock levels due to stockpiling of raw materials at HWR.

ii) Stock figures include an amount for stock of Manual equipment from 1973 onwards.

iii) Approximately 200 Autolynx Fastpak rectifiers were bought back from Airco in April 1974, thus disprportionately increasing the stock level for that year.

However, the data for 1976 and 1977 show a large increase in stock followed by a substantial decrease, which are not in keeping with the level of sales and production for those years. This is apparently due to problems of stock levels and stock recording at HWR, both of which are now being brought under control.

C. The Ramsgate Factory as a Production Unit

a) Sales (see Graph 10A) (G.18)

Since HWR have always sold 80-90% of their output to BOC, and very little on the open market, patterns of sales follow the fixed and direct pattern of fixed and direct costs very closely.

The mark-up on fixed and direct costs until 1972 was fairly consistent at 25%.

Since 1972 when BOC took over the HWR company, transfer price consisted of standard cost plus mark-up to cover fixed costs (25% in 1973, now at 40%).

However, the standard costing system although introduced in 1973 was only very approximate, being done individually for the first time in 1976. (Direct costs were actually 90% of sales in 1973.)

Consequently with all the circumstantial and accountancy changes in the period, sales figures or price per unit figures will not mean a great deal.

b) Costs

NB. Data on costs for the HWR factory is fairly consistent throughout the period.

(i) Fixed costs

Fixed costs at HWR have grown at 13% p.a. c.g. rate, rising from 11% to 17% of total product costs over the period.
Administration costs, dominated by salaries and pensions (85%), form increasingly the largest part of fixed costs, having grown at 19% p.a. c.g. rate to the present proportion of 70% of fixed costs.
Establishment costs form 18% fixed costs, having grown at 11% p.a. c.g. rate. These costs consist of rent, rates, maintenance of equipment etc.
Financial costs have declined over the period since this category used to include a substantial amount of loan interest on loans from BOC.
The balance of fixed costs fluctuates according to particular items being included, e.g. Business consultancy fees, costs of computer facilities etc.
However, total product costs are certainly dominated by direct costs, now forming 83% of the total.

(ii) Direct costs

Since materials form approximately 82% of direct costs, with labour forming the other 18%, cost of materials certainly dominates direct costs and hence total product costs at the Ramsgate factory (see Graph 10A). (G.18)

a) Materials

Constituent parts of material required in the manufacture of rectifiers are :

Copper 38%

Laminations 32%

Metals & Bakelite 13%

Electrical parts 17%

Consumables, less than 1%

1) Copper (see Graph 11A) (G.19)

Copper prices obtained from the London Metal Exchange, when deflated, show an overall average decrease over the period 1968-1971 of 6% p.a. compound rate of decline.

The small amount of data (1973/74 onwards) on standards of copper prices used in standard costing at HWR show approximately the same trend of 6% p.a. compound rate of decline.

2) Laminations (see Graph 12A) (G.20)

Standards used in standard costings show a slight increase 1975 to 1977 of 1.1% compound g. rate per annum, but this result is not statistically significant. We conclude that the cost of laminations is fairly constant.

3) Steel sheet

This is the only other part of materials for which data was readily available. The price of steel sheet, when deflated, showed a 6% p.a. c.g. rate increase over the four years of data.

However, as copper prices must dominate the price of steel sheet, and cost of laminations has not increased, we conclude that the cost of materials has not increased over this period, 1974-1977, and take this as indication of the picture for the period 1966-1977.

b) Labour costs (Graph 10A) (18% of direct costs)

Labour costs have been fairly constant throughout the period, rising slightly during boom years, but not proportionally keeping pace with swings in production levels. The policy has been when production is low, to engage workers in other tasks. Hence, in this particular context labour costs are more in the nature of a fixed cost.

Summary of the production unit - HWR factory

Costs

The majority of costs incurred at HWR is direct cost (84%) growing at 8% p.a. c.g. rate. Most of direct costs go on materials (82% of direct costs), and it is materials cost which is causing the growth in costs. However, as far as can be discerned, absolute costs of raw materials is not increasing at this rate.

Labour costs are a fairly constant proportion of the total.

The increase in fixed costs is caused by the increase and administration and running costs of an expanding establishment. However, these costs have grown at a greater rate than the rate of increase of production.

D) MK Costs

Direct costs

No further data is available on this.

Fixed costs

Of fixed costs incurred at MK, manufacturing costs (Factory or operational costs, transport costs, warehousing and distribution) form approximately 35% of the total with marketing costs being 40%, R & D 15% and miscellaneous 10%. (Considering 1972 figures when marketing costs were fully borne by MK).

As accountancy changes have been so marked during this period, no further analysis has been done on the breakdown of fixed costs.

E) Dynamics of the separate product groups MIG and TIG with PLASMA

MIG with an apparent four year cycle in sales (see Graph 2A) appears to be the part of the business dependent on the state of the underlying mechanical engineering business. Investment in MIG equipment takes place when times are good, and thus seems to be a matter of choice and not necessity. Hence sales of MIG depend on a lively attitude to marketing and development, and benefit from the frequent introduction of new models

In the first few years, production of MIG is confined to steady output of a few popular models. Then we get the introduction of the SMR range in 1969-71, which, after a poor start in 1972, picks up to reach peak sales in 1973 and production in 1974. Although the range is wide, each model costs less to produce than elements of the previous range, and so the overall effect is that of cost reduction.

Sales and production output decline from 1973 to 1976, when the new Transmig range is introduced. The range is trimmed slightly and some new models experience extreme cost reduction from value engineering, others just receiving cosmetic improvements. A rise in sales and production levels follows in 1977 with continued cost reduction.

The conclusion is that MIG products have experienced cost reduction due to the effects of design engineering ; and these efforts expended on design have also, after initial slump, boosted sales. The pattern of constant actual price increases for MIG rectifiers from BEAMA data, presents a picture of increasing profit margins on MIG products which conflicts with the pattern for the whole business.

<u>1966-68 Detailed Analysis</u>

Early production consists of the manufacture of one small, popular model, the MRCS 200B, and three fairly heavy MIG sets, STR 650, SPR and SMR 400, all fairly costly to produce. Sales during this period is fairly steady, as are production levels.

<u>1968-70</u>

There is an increase in production due to the introduction of the Autolynx model, and a significant increase in the manufacture of SMR 400's. OEM Sales of MIG increase by 150%, mainly due to large sales of STR 650's to Rockweld.

Sales increase to reach a peak in 1970, coinciding with a peak in production However, costs per unit rise fairly sharply over this period.

<u>1970-72</u>

This period sees the introduction of the SMR models, most of which are in the middle output range. It is difficult to assess whether some product lines ever pick up all the sales of the previous model, as the period coincides with a general decline in the business cycle.

The overall substantial cost reduction indirect costs per unit (standard costs), even though combined with a probable increase in average fixed costs due to increased width of the range, has an overall effect of cost reduction which continues until 1972.

1972-74

This period sees another boom in MIG production, with increases in all parts of the SMR range, particularly the 200's and 300's, to reach a peak in 1973/74. It may be noted that the peak in production lags the peak in sales by a year, as in the total business. Cost reduction continues, with irregularities caused by the lack of coincidence of sales with production.

1975/77

During this period there is a goos general trimming of the range, with the introduction of the Transmig series of machines. Some of these models are updated versions of old models with only cosmetic changes, achieved at the save cost of manufacture. Production having slumped in 1975 and 1976, picks up in 1977 when the new models start proving popular, particularly the well-designed TM 350.

Sales achieve 10% growth in 1976/77, after having reached the lowest point since 1969 in 1975/76.

Cost reduction, though seeming rather poor in 1974/75 is again achieving good results in 1976 and 1977.

Conclusion

Cost reduction in MIG is achieved with the introduction of new, lower cost models. Individual models do not seem to experience a reduction in direct costs even when produced over a fairly long period of time, i.e. cost reduction is a product of engineering design and not of production experience.

TIG (and PLASMA)
General dynamics of the TIG business consist of a very smooth pattern of sales with a steady increase (growth rate 6% p.a. c.g. rate). This indicates that purchases of TIG equipment continue independently of the state of the economy, and are thus treated as a necessity by the users.

Production, however, shows a pattern of large fluctuations, with a rather longer cycle length than MIG.

An investigation of the range and cost of TIG models reveals initial production of an expensive range, then swinging down through the middle range, followed by the introduction of a cheap range in 1972. Then in 1976 there is a trend back to the more expensive models with the introduction of some of the new, sophisticated Transtig models.

These changes in range will obviously be reflected in costs per unit, and this will be exaggerated by the swings in production output.

The conclusion is that the market is a captive market, with BOC Arc Equipment dominating the manufacture of TIG products. The policy seems to have been :

(i) reliance on old proved product range until 1976

(ii) introduction of cheaper lighter models in 1971-1973

(iii) rationalisation of the range in 1974-5, and introduction of Transtig range in 1976, some of which are far more sophisticated and hence more costly models.

Detailed analysis

TIG, PLASMA, and AUTOMATICS

1966-69

Production of TIG rectifiers reaches a peak in 1968/69 with all original models in the AMR, ADR and MNR range reaching peaks of production.

TIG sales are fairly steady and sales of automatics form a fairly large part of the business at this stage,

Cost per unit is falling during this time, partly due to the swing towards the slightly less expensive ADR's and MNR 400.

1970-71

There is a gradual decline in all standard models, and rapid phasing out of the MR 375.

OEM sales suffer a large drop in automatics, with production falling by 45%.

Sales of TIG suffer a very slight decline.

Costs per unit during this time increase sharply although this is exaggerated by the sharp fall in production.

1971-74

There is a steady increase in production in all parts of the range, with the introduction of the TDC 150 and TAR 300 increasing the cheaper end of the range. ADR 300 and MNR 300 enjoy great popularity, particularly in 1973/74.

Sales of TIG and PLASMA during this period show steady growth, but OEM sales declining steadily.

1975-77

During this period, the rationalisation of the range occurs. The AMR and ADR ranges are each replaced by one unit of greater specification, the Transtig DC 250 and AC/DC 375 respectively. Other changes to models are cosmetic, with very slight increase in costs.

Production shows a decline in 1976 which picks up very slightly in 1977, but does not recover to 1974 levels as MIG does.

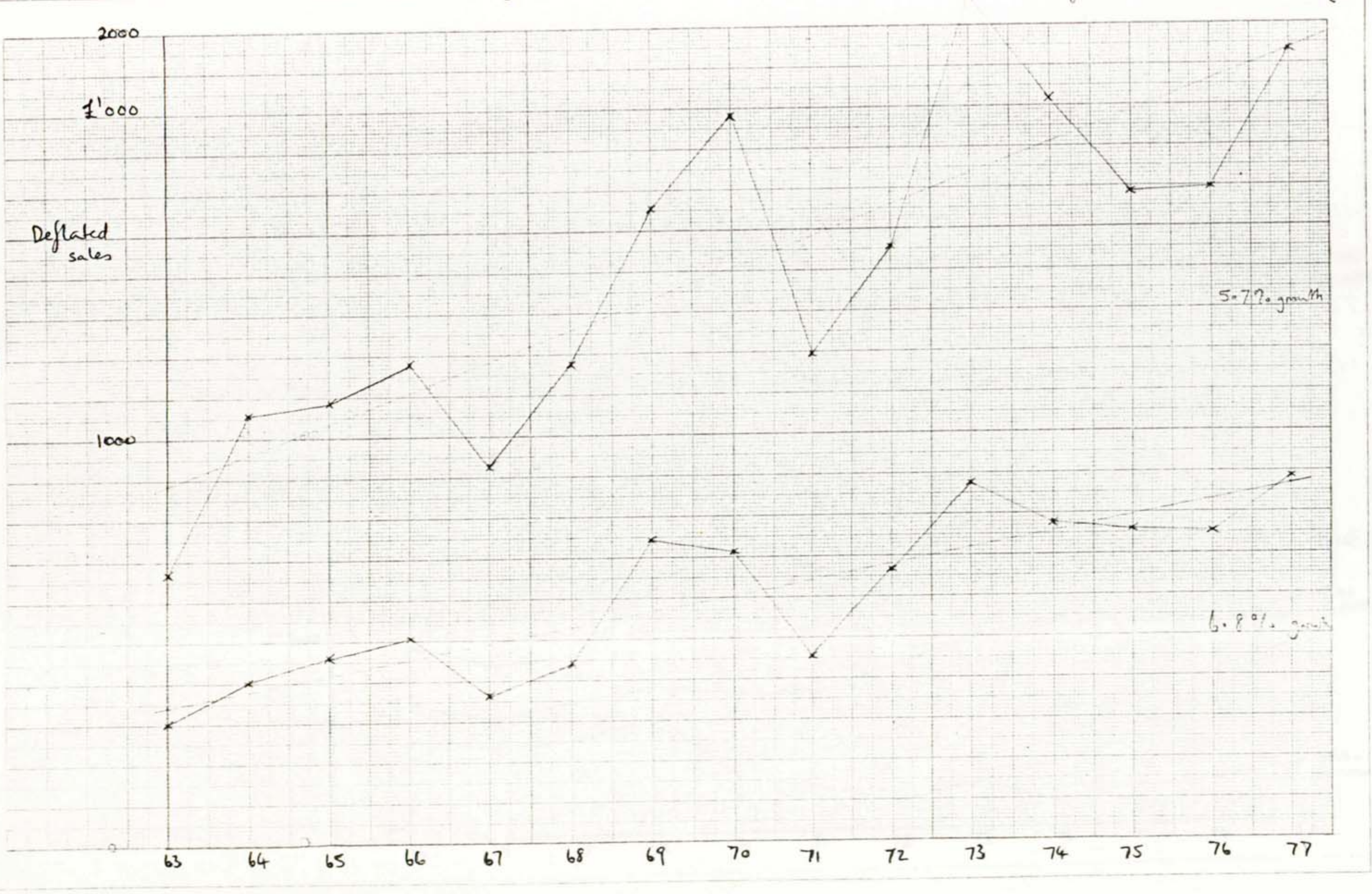
Sales, however, do recover, demonstrating the marketing of a lesser volume of more expensive products.

Sales to OEM's show a steady increase since 1974, although production of automatics declines.

The resultant effect on costs per unit is that of a decrease 1975/76, but a sharp increase in 1976/77.

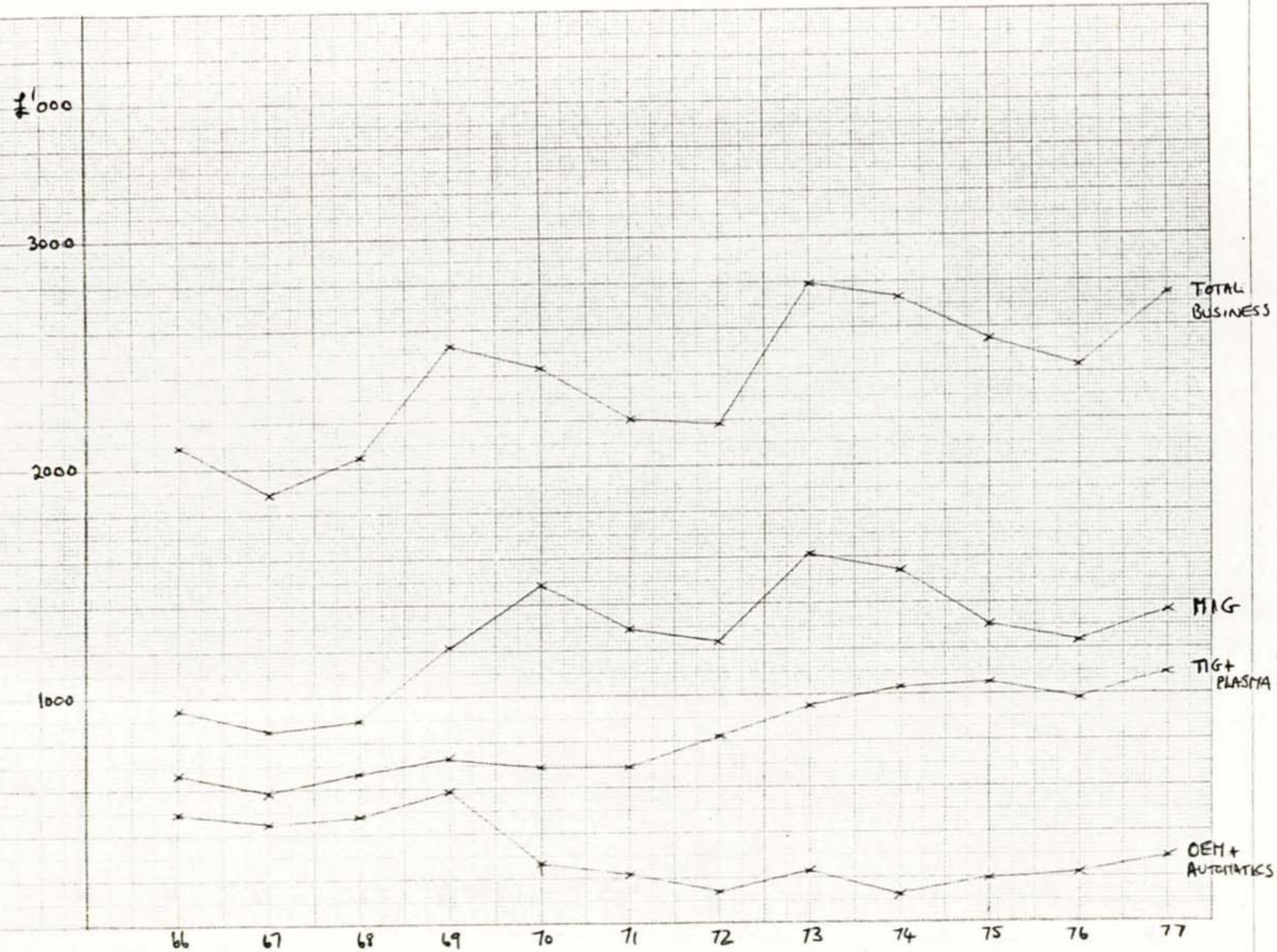
Industry & BOC Sales from BEAMA Data (Deflated)

Graph 1A (G.9)

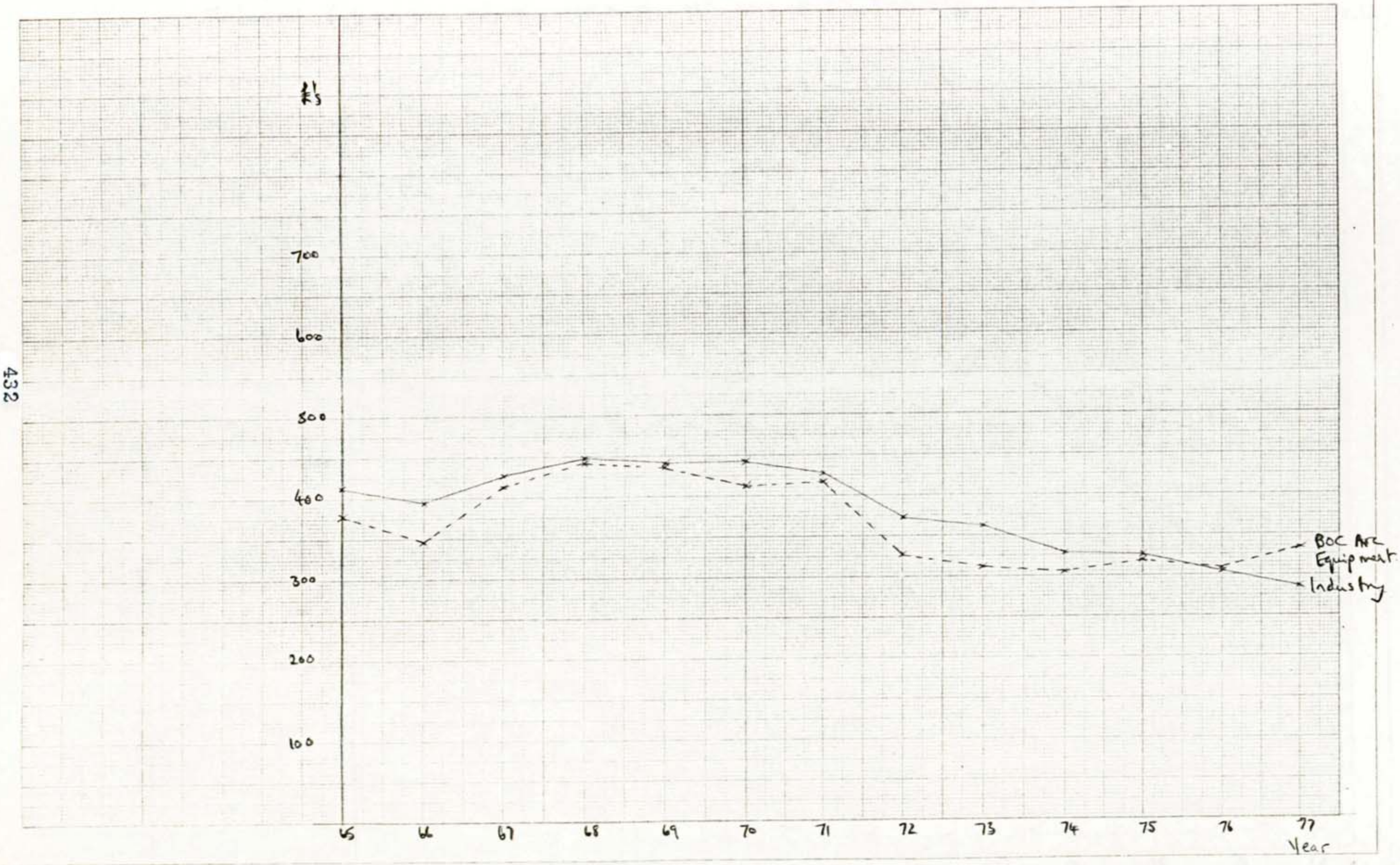


Graph 2A
(G.10)

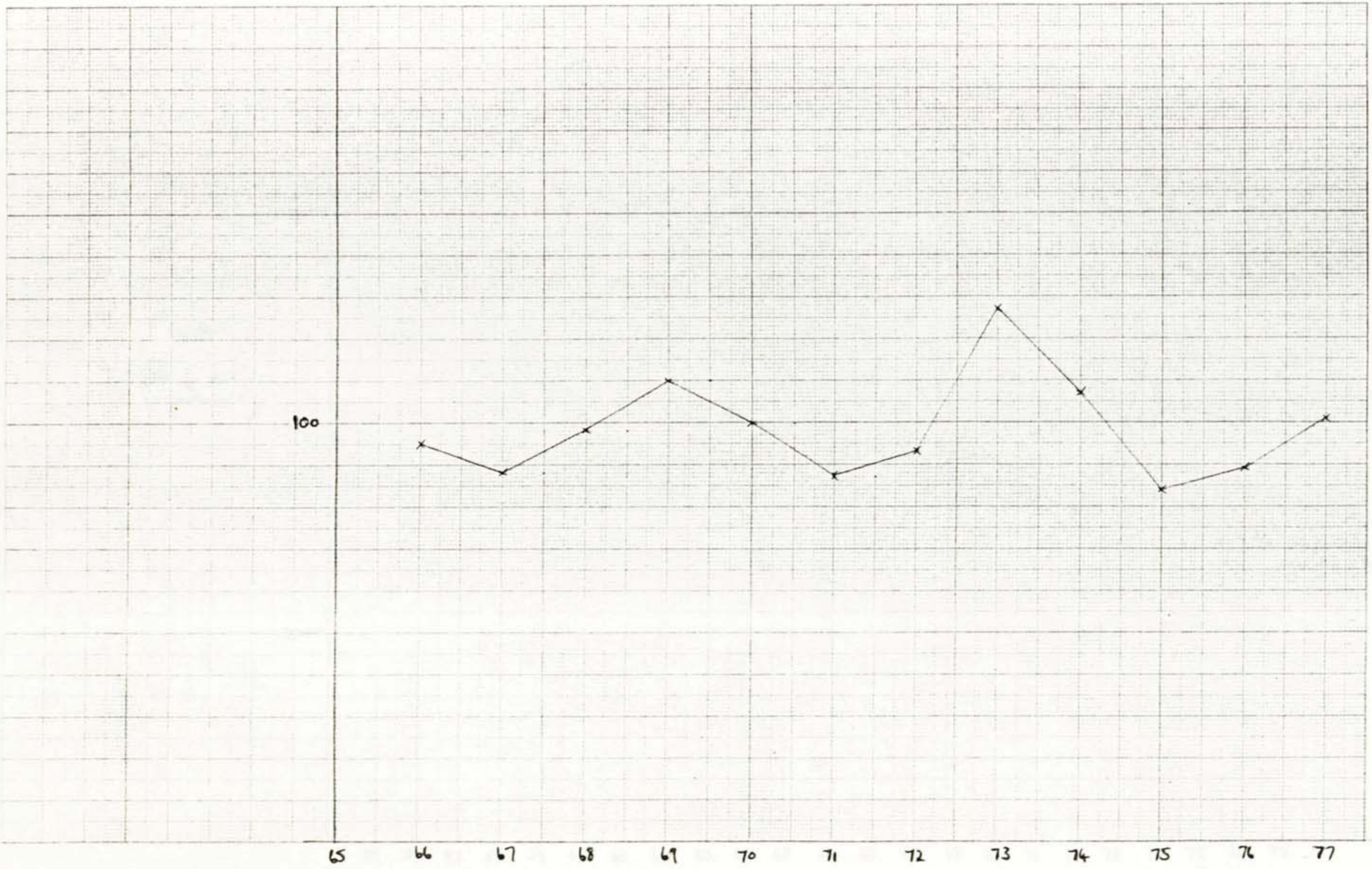
Total Business Sales 1966-77 (BOCAE + HWR)



Average price per unit (BEAMA data) BOC AE overtakes UK industry average in the last two years (1976-77) Graph 3A (G.11)

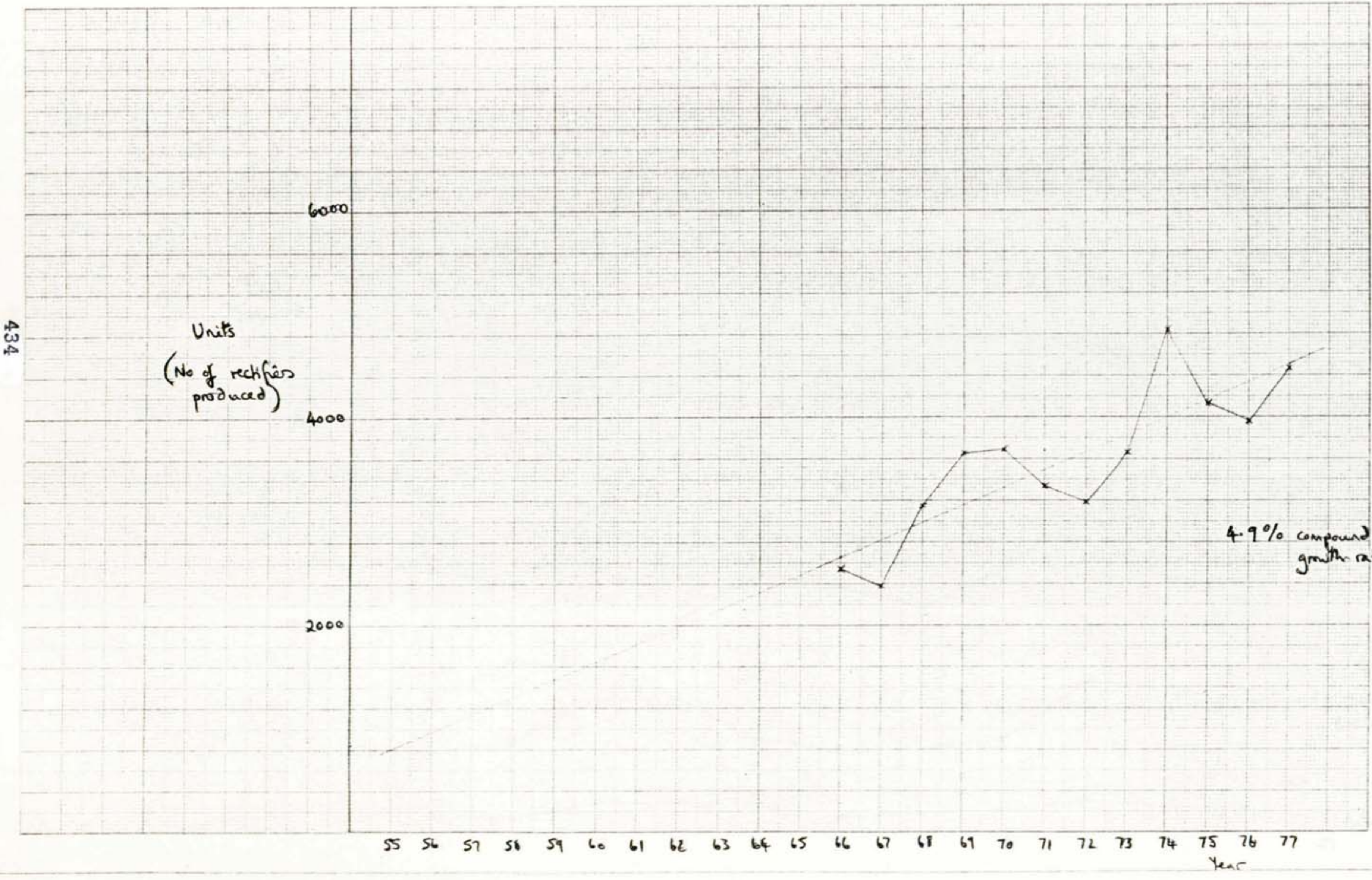


Mechanical Engineering : volume index of net new orders, seasonally adjusted (1970=100) Graph 4A (G.12)

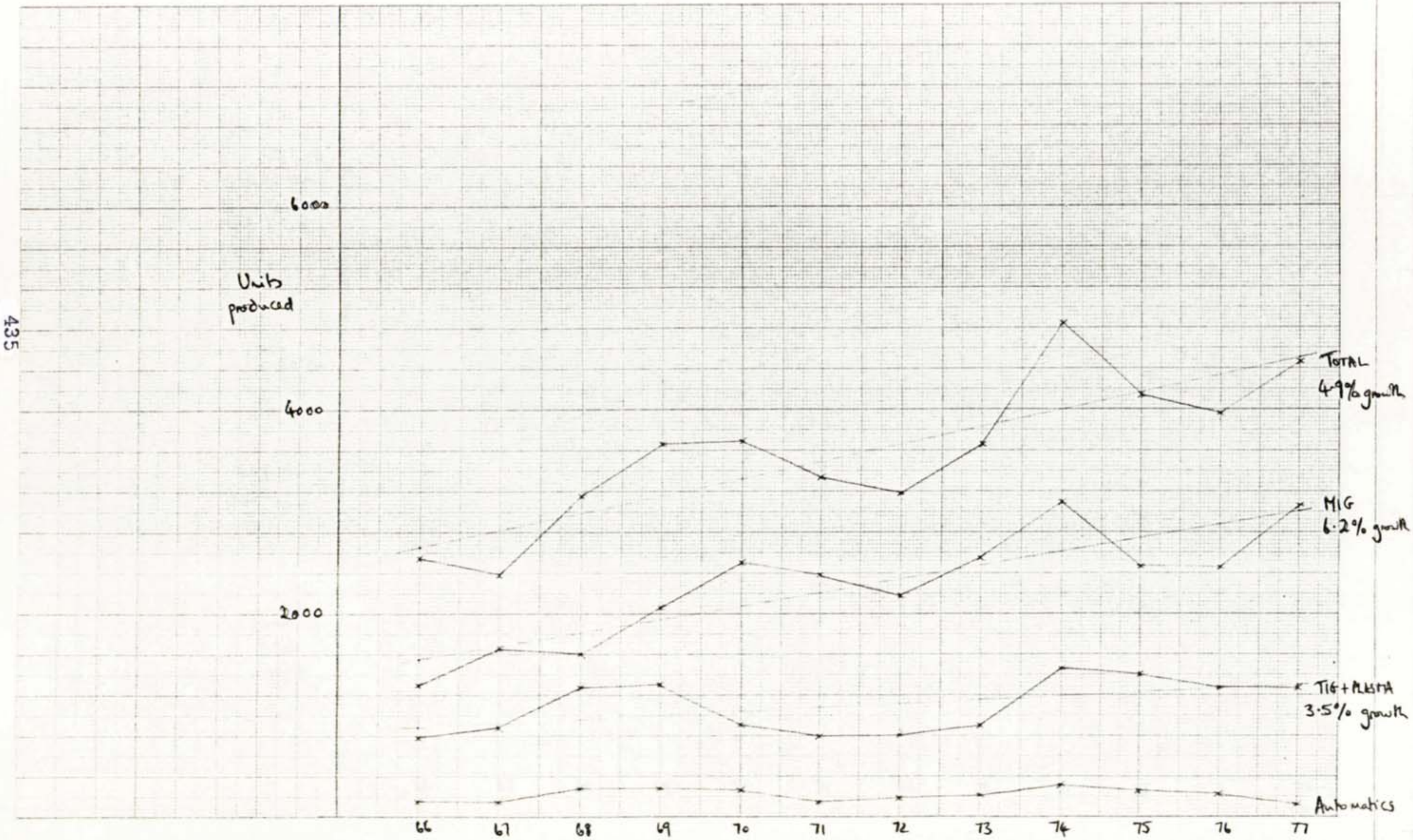


Graph 5A (G.13)

Growth in production : a long term views of volume sales for joint business (BOC AE + HWR, 1966-77)

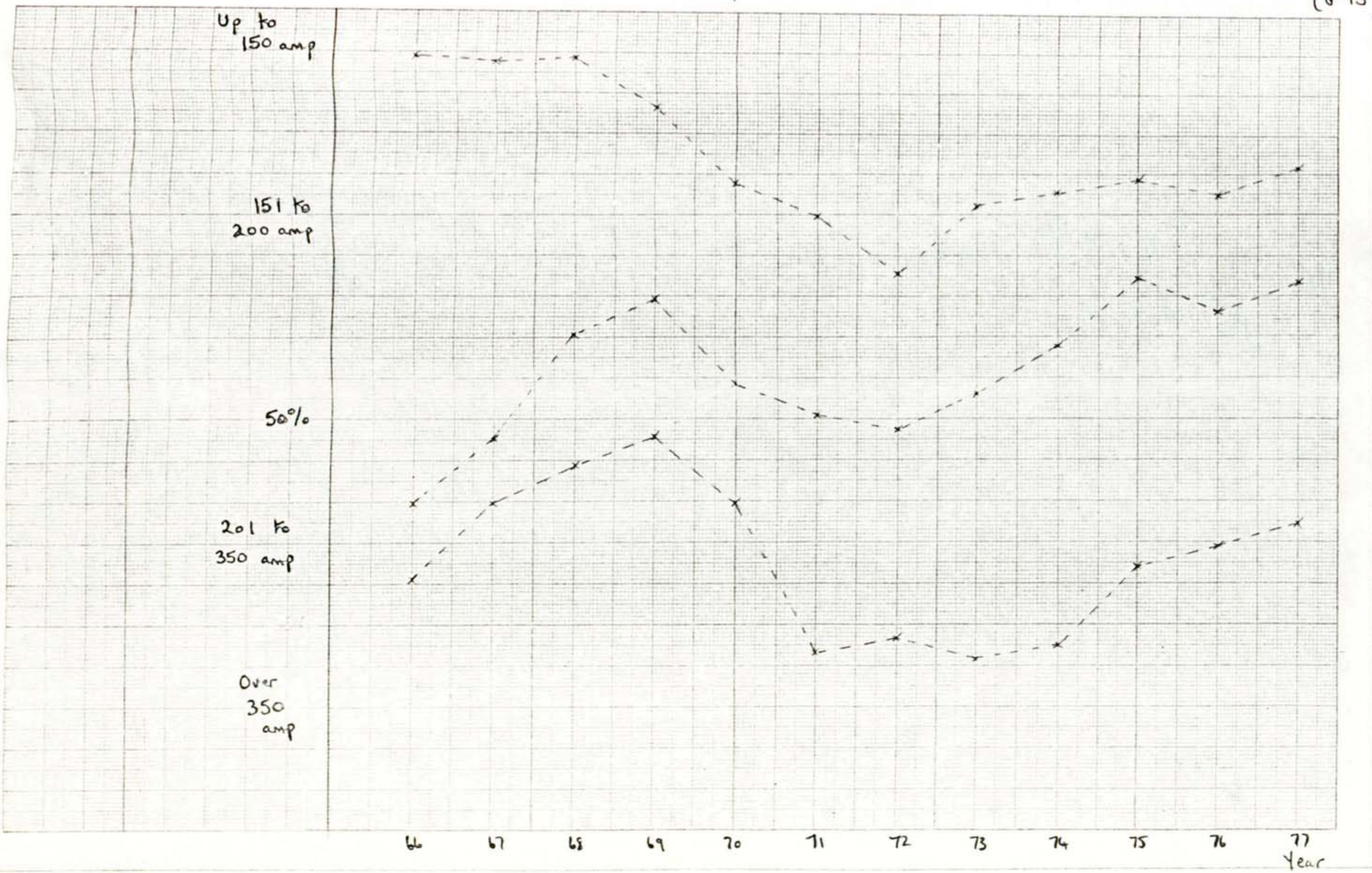


Volume of output of rectifiers from the production unit, HWR (1966-77) Graph 6A (G.14)



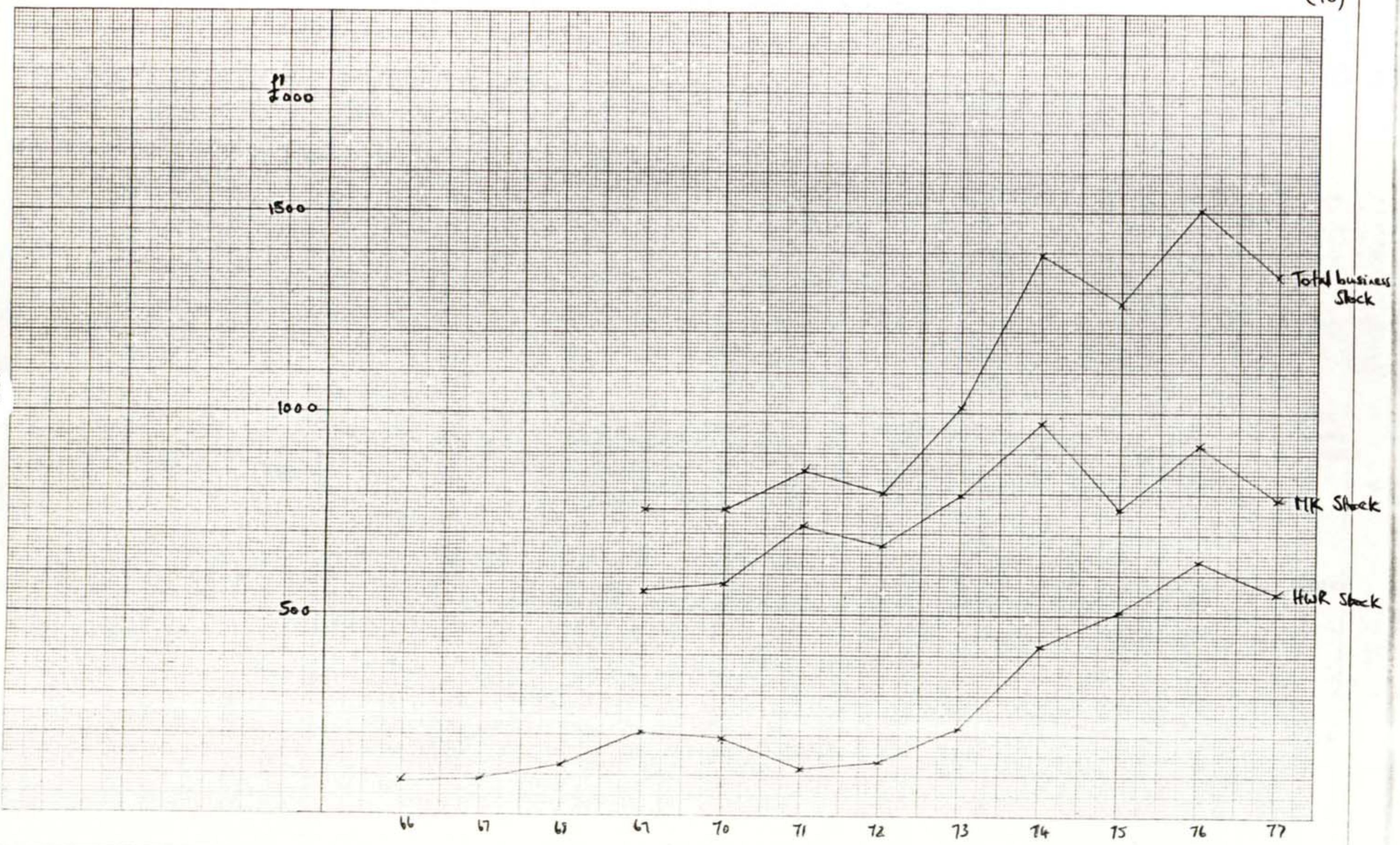
Percentage composition of product mix in output from HWR (1966-77)

Graph 7A (G 15)



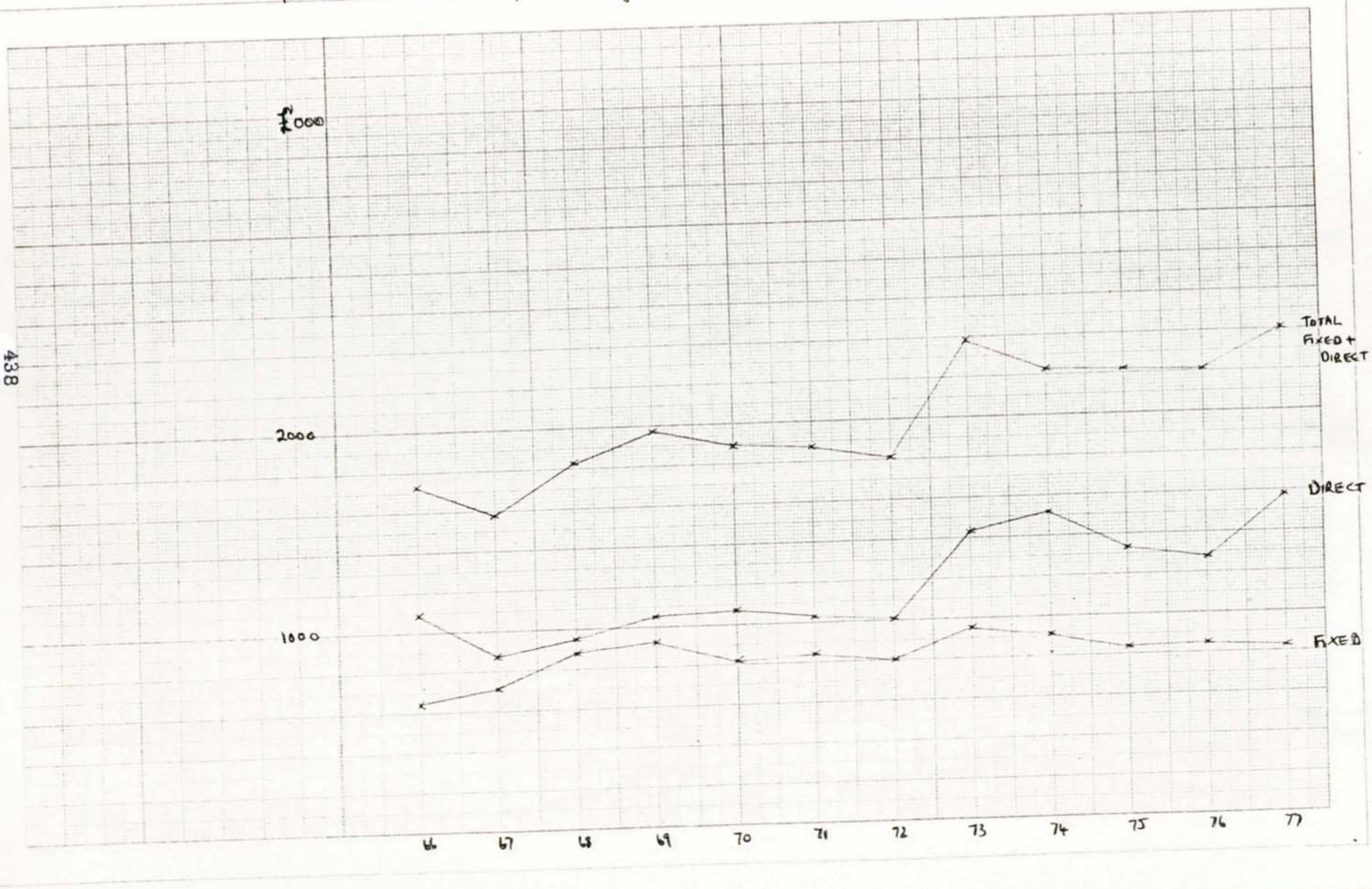
Total business stock increases over the period 1966-72, mostly due to increase in stock at HWR

Graph 8A (16)



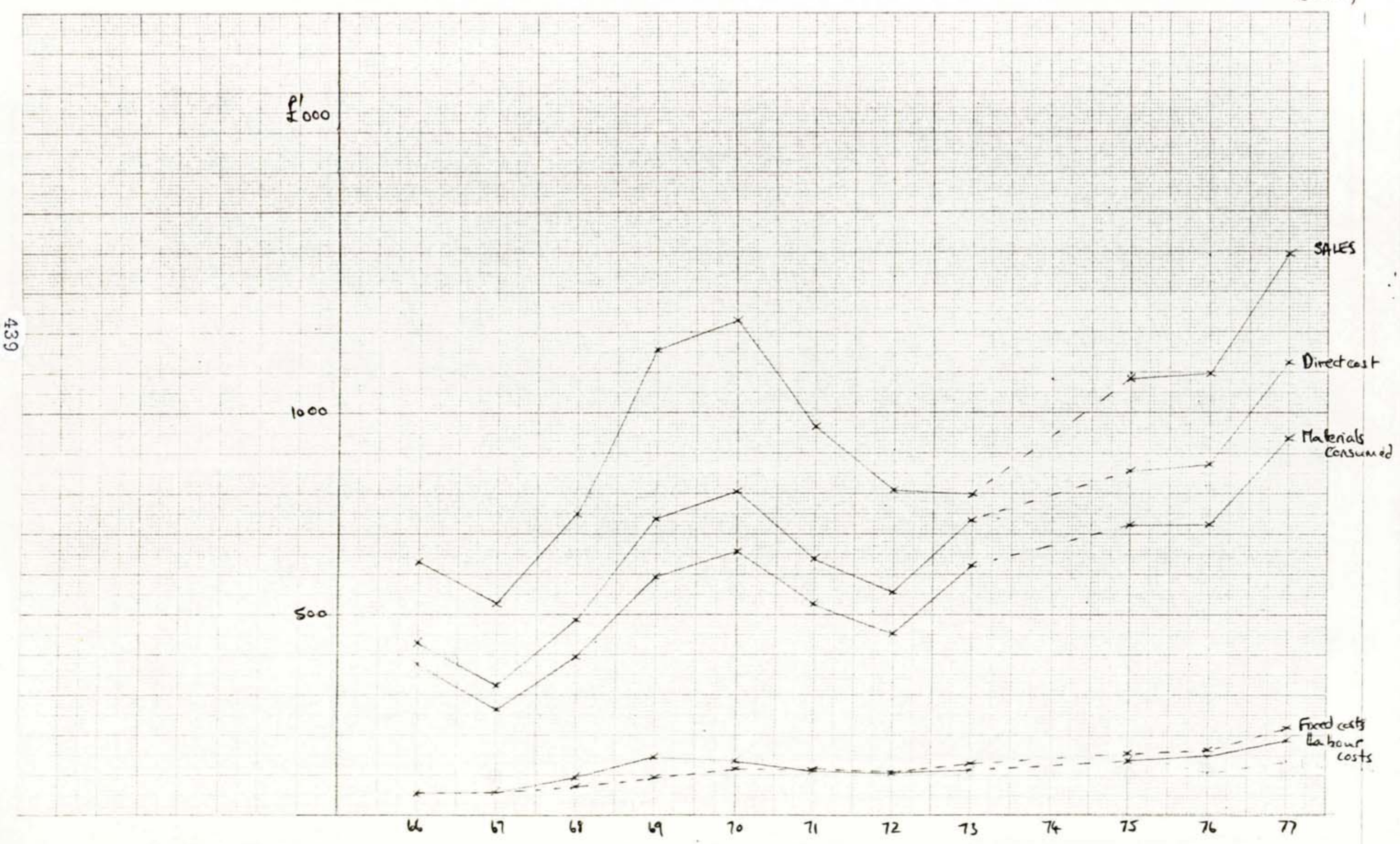
Graph 7A
(G.17)

Total business : composition of fixed and direct costs



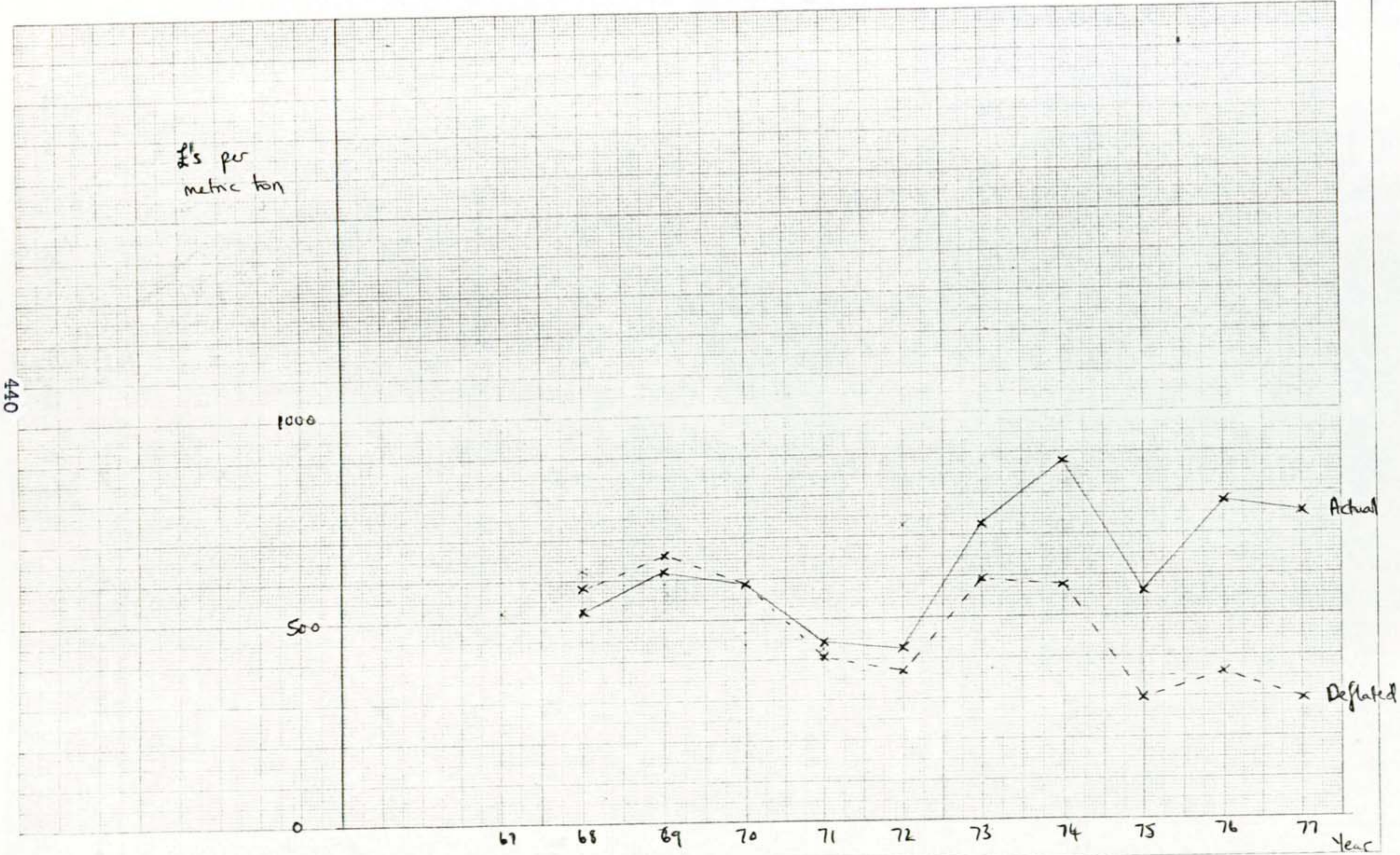
Sales and costs at HWR Deflated, 1966-77

Graph 10A
(G.18)

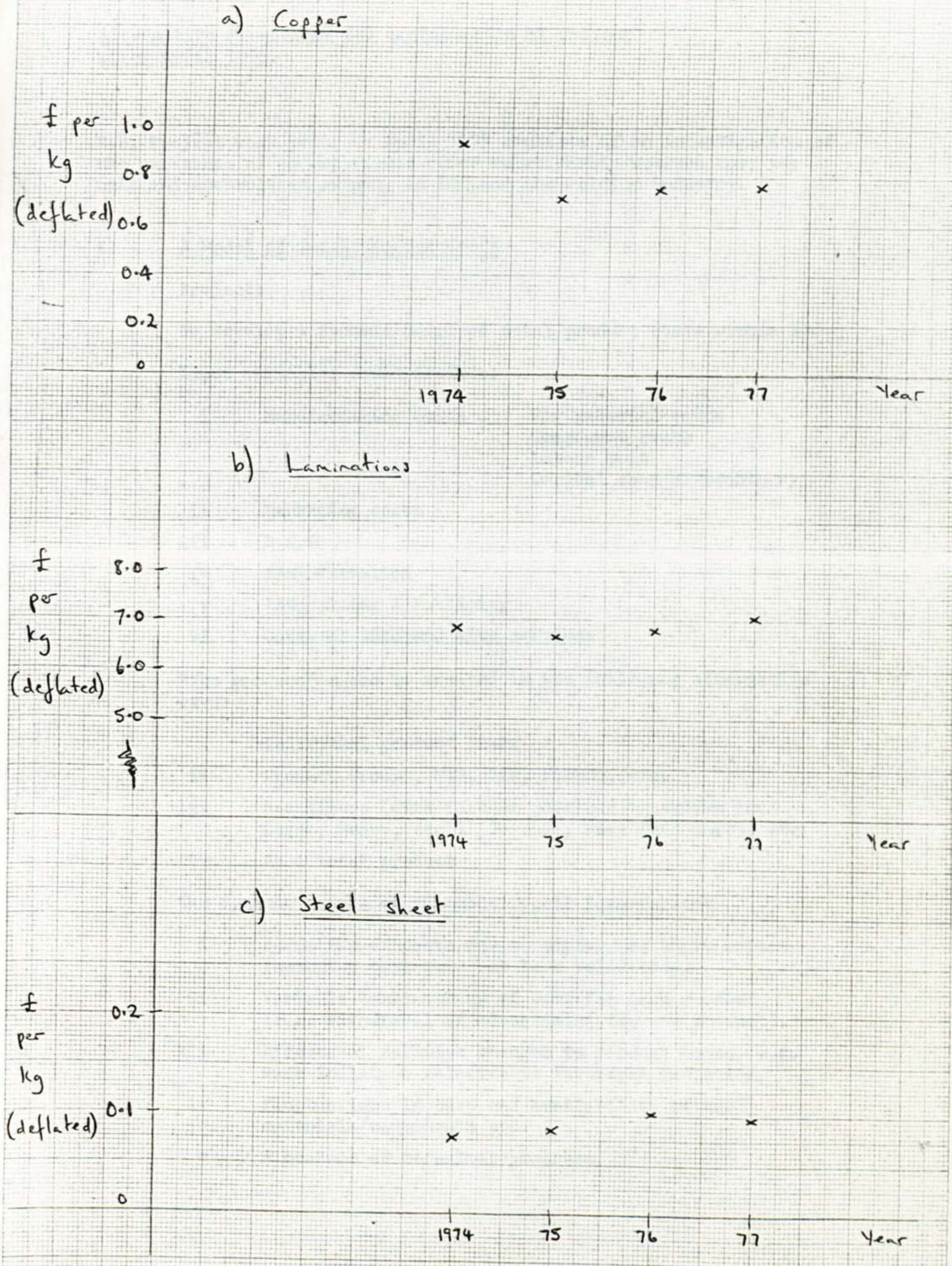


11A (G.19)

Copper prices – source: London Metal Exchange.



Graph G.20 (12A). Standard costs of materials used at HWK, 1974-77 (deflated)



Source of data: Appendix E. 3.1

APPENDIX G 2

Alternative directions for continuation of project after April 1978.

N.B. Project work prior to April 1978 consists of an investigation of the existence of an experience curve relationship between cost per unit and accumulated output, in BOC and the welding industry.

1 A Model of Total Product Costs

Project:

To develop a dynamic model of total product costs within BOC.

Input variables could include:

i Manufacturing costs : Raw material costs
Component costs
Labour cost
Capital cost of machinery

ii Marketing costs

iii R & D

iv Administration

v Advertising & Publicity

vi Costs of site and site services

"The product" could be treated in the following alternative ways:

i Individual product lines

ii Product Groups, MIG, TIG, PLASMA, etc.

iii Rectifiers (with further possible breakdown into Light, Heavy, etc.) Torches, wire feed units, etc.

iv As a total product

The dynamic nature of the model would incorporate:

i Reduction of costs due to experience curve effect (assuming that this has been validated).

ii Variable combinations of cost for each product (e.g. withdrawal of advertising for one product).

iii Effects of relative changes in product costs, e.g. wage inflation relative to 'average' inflation.

iv Fluctuations in cost and availability of raw materials/components etc.

v A measure of technical progress.

Uses of the Model:

i Cost estimation for pricing, and in forecasting.

ii Selection of cost-optimal product mix.

iii Appraisal of the effects of cost-reduction schemes on product costs in order to aid decision-making.

iv Evaluations for make or buy decisions.

v Evaluations for replacement of capital equipment decisions.

2. Corporate Planning Model I

Project:

Assuming the verification of an experience curve within BOC and Industry; then using this as a base, develop a model which aids the corporate planning process in some particular way.

i.e. This will be a limited model performing one of the following functions:

i To indicate the optimum market share using criteria of net present value, given certain circumstances, which can be either static or dynamic.

ii To evaluate the best market share strategy to reach given company objectives, given existing market shares of BOC and competitors.

iii Develop model for ascertaining possibilities of and requirements for achieving market share objectives, given certain relevant competitive configurations.

Uses of Model:

i To give a rigorous examination and evaluation of various strategies arising from acceptance of the experience curve effect in BOC and the industry.

ii To aid decision making in corporate planning.

3. Corporate Planning Model II

Project:

This project would encompass the field of project (2), being a more complete corporate planning model. The model would predict the behaviour of certain parameters of the performance of BOC under varying strategic plans. External environment factors affecting performance could also be incorporated into the model, if required.

The parameters of performance would consist of:

- i Market share (possible market share relative to competition).
- ii Profit, yearly and accumulated.
- iii Cash flow.
- iv Return on capital invested.

Input variables related to strategic plans:

- i Volumes of output required.
- ii Predicted competitive reaction.
- iii Investment required over time period.
- iv Anticipated growth rates of BOC and industry.

N.B. Assuming the existence of an experience curve relationship in BOC and industry, this would be incorporated into the model.

External/other factors which could be incorporated:

- i Trade cycle.
- ii Product life cycles.
- iii General economic trends in the environment.
- iv Segmentation of the industry into product groups, with resultant separate effects of strategies on each, and possible interactions between them.

Uses of Model:

To evaluate the cost and benefits of strategic plans in terms of the parameters given.

4. <u>Marketing Strategy Research</u>:

Project:

To develop ways in which the demands of strategy can be met, in terms of volume of output.

This would include:

- i Market research in terms of product/market mix, geographical considerations, etc.
- ii Survey of advertising and packaging within BOC and industry.
- iii Investigation of pricing policies and strategy.
- iv Investigation of selling structure presently operating in the Company.

v Investigation of distributor outlets etc.

vi Study of OEM sales.

vii Acquisition possibilities.

viii Market research on Company/product image for BOC and competitors.

Uses of Project:

i To enable the Company to achieve the volumes of output required to achieve the desired growth.

ii General background for forecasting, decision-making, etc.

5 <u>Design of formal system for corporate planning information</u>

Project:

Investigation and evaluation of the end users of the system and their information requirements, followed by

Design of the following:

i A data base for corporate planning information.

ii A system for data collection.

iii Incorporation of data into the system.

iv Disposal of relevant information to end users.

Uses of the project:

i The immediacy of information for planning purposes.

ii Monitoring the actual performance of the Company against the strategic plans.

6 <u>Investigation of the basis for strategic planning</u>

Project:

The project would require:

i Investigation of the present basis for strategic planning and decision-making.

ii Evaluation of the results of using the present basis.

iii Survey and examination of the other methods and conceptual bases for strategic planning.

iv An evaluation of the possible benefits of using an alternative strategic planning base and methodology within the Company.

Uses of Project:

Comparative evaluation of strategic planning procedures.

7 Evaluation of cost-reduction opportunities

Project:

An examination of the general cost structures and history of these within the company, followed by an investigation of cost reduction opportunities, and an evaluation of possible benefits.

Possible cost centres:

a Manufacturing

b Marketing

c Publicity and Advertising

d R & D

e Administration

etc.

There would be two avenues possible for investigation of cost reduction:

i Actual possibilities for cutting costs.

ii The impact of cost reduction schemes on the marketing potential of the product.

Uses of Project:

i Discovery and evaluation of cost reduction schemes.

ii Evaluation of the impact of charge on the market/marketability of the product.

8 Investigation of component parts of strategic plan

Project:

The project would consist of an investigation of the parts played by the strategic plans of component departments/cost centres of the Company in the overall strategic plan.

The are possibilities of a model for examining:

i Interaction of the various component strategic plans.

ii Effects of the component parts on the strategy as a whole.

iii Effects of failure of component parts to achieve their objectives on the performance of the whole Company.

Uses of the Project:

i As a device for helping to monitor the progress of the overall strategic plan.

ii For evaluation of aggregation of component plans and comparison with overall plan.

iii To aid decision-making on component strategies.

P. Thornley

PT/SSH
24 February 1978

APPENDIX G3

FUTURE WORK TO BE DONE IN IHD PROJECT - MRS P. J. THORNLEY

Report on input from individual board members of BOC Arc Equipment.

Meetings with individual board members produced much fruitful discussion and feedback of ideas on the following topics:-

1. Experience Curve model for unit costs

Suggestions covered three areas:-

1.1. Refinement of the experience curve model to avoid the problem of increased specification of the product.

1.2. Alternative models to be investigated; primarily with dependent variables of volume and time.

1.3. Reasons for unit cost reduction at BOC Arc Equipment not being in line with the rest of the industry (i.e. support was given to this alternative hypothesis in the original report).

1.3.1. The most crucial area for effective cost reduction in the arc welding equipment business is thought to be that of product design.

Problems are:

i) The matching of product specification to market requirements.

ii) A general overspecification of products in BOC Arc Equipment, probably as a result of failure in (i).

1.3.2. Problems concerning management of the Thanet factory, in particular:

i) The history of management at the factory.

ii) Integration of the factory into BOC Arc Equipment.

iii) Continuing problems of communication and polarisation of attitudes due to the split sites.

1.3.3. Other factors such as:

i) Present investment for future expansion.

ii) A lack of united effort between departments.

Cont'd......../

2. Future direction of the project

There was some support for a limited corporate planning model for evaluation of the costs and benefits of attaining market share objectives. Another possible area of research suggested by the discussions is the relationship between marketing variables of market requirement, product specification, price and cost.

However, the majority of members felt that the evaluation of cost reduction opportunities, possibly with some cost modelling, would be the best direction for future work.

This would be of great value to the company, as well as forming a natural progression for the project.

3. Future courses for action

Parts 3.1. and 3.2. are an extension and validation of the work accomplished so far:

3.1. Verification of one of the alternative hypotheses:

i) All companies in the industry are in a similar position to BOC Arc Equipment.

ii) BOC Arc Equipment are in a worse position than most companies in the Industry. Data is being provided from Socomé and possibly from Airco. French, German and U.S. Welding Industry statistics will also be used for comparison purposes.

3.2. Investigation of alternative models and/or refinements of the experience curve model.

3.3. Under the hypothesis that

i) There is an experience curve for unit cost in the arc welding equipment industry.

ii) BOC Arc Equipment are on such a curve but its 'slope' is not as 'steep' as the average unit cost experience curve for the industry.

Cont'd......./

BOC Arc Equipment need a strategic plan for the attainment of the objective:

Unit cost reduction which will bring unit costs of BOC Arc Equipment to a level equivalent with those of industry, within a time scale of five years.

I propose to construct a five year strategic plan for achievement of this objective, involving the following actions:

1. Set an overall target unit cost for the end of the five year period, based on the experience curve model, with projected volumes of output set by corporate planning/marketing departments.

2. Analyse the structure of costs by function e.g. Finance, marketing, R & D, production. Determine the effect which each has upon unit costs and consequently rank them by importance.

3. To further breakdown costs by department, either for all functions, or for the most important and perform the same ranking procedure.

4. To continue this procedure until an optimal useful level has been reached for the most important areas.

5. To use these findings to construct a 5-year strategic plan for the achievement of the target unit cost reduction. This will involve:

   i) Strategic plans for overall cost reduction giving priorities of function/department in the cost reduction program.

   ii) Target cost reductions for each of the five years.

   iii) Shorter term programs for achievement of yearly cost reduction targets.

   iv) A breakdown of operational plans where it is considered necessary and beneficial.

6. Monitoring of results.

It is hoped that this plan will be incorporated in the strategic plans for 1980 - 1986, constructed in Oct/Dec 1979.

PJT/PVR
27.7.78

MINUTES OF MANAGEMENT MEETING HELD ON 2ND AUGUST, 1978 AT MILTON KEYNES

PRESENT : Mr R B Edwards
Mr R Lambert
Mr B G L Switzer
Mr R J Jones
Mr M G Leigh
M. J Elsner
Mr R J Collier

APOLOGIES: Mr R H Anderson
Mr M Cannon
Mr N J Dobson

ACTION

1. P.J.Thornley Project - Future Direction

1.1 Paper presented outlining the proposed future direction of the 'Experience Curve Project'. It was felt that,

a) the amount of work proposed could not be completed in the timescale

b) verification of the experience curve hypothesis and the position of AE on the curve was needed before any further work can begin

c) the operational cost reduction programs were felt to be a problem to a non functional person

1.2 The Board agreed with the broad proposals presented but felt that actions 1-4 should form the basis of the project work, with action 5 being incorporated as a result of liaison with departmental personnel.

1.3 It was further felt that the project direction should be flexible, as the availability of data may cause a revision in its scope.

1.4 Interim report to be produced for the November meeting, with the aim of incorporating it into the strategy review. RJC/PT

1.5 MGL to liaise with SNS on the cost data that is available. MGL

1.6 Copy of the preliminary report to be sent to R Lambert. RJC

2. Minutes of Previous Meeting

APPENDIX G4

Report on statistical evidence for selection of a model for unit price and cost at BOC Arc Equipment

1. Scope of report

Analyses of data on volume and value of sales of;

a) Arc welding equipment from BOC A.E.

b) Arc welding equipment industries from UK and other countries.

c) Products in various other industries.

Data on costs was also used where available.

2. Analysis

2.1 Investigation of any significant correlations between

a) Average price or cost per unit.

b) Each of time (in years), annual output volume, and cumulative output.

2.2 Forms of model tested;

a) Log/log model

b) Linear model

c) Log/linear model for BOC A.E. and UK industry data.

2.3 The model was then tested to see whether the inclusion of more than one variable significantly improves the fit.

3. Data

3.1 Of the original 32 sets of data, 14 were discarded as the number of data points were inadequate. (6 or less)

3.2 Summary of 18 data sets used in the analysis

No. of sets	Source	Dependent variable	Product
1	UK Industry	Ave price	Rectifier
2	BOC AE	Ave price/unit cost	Rectifier
8	Other countries	Ave price	Varies from rectifiers to electric welding machines.
4	Sparklets Ltd	(Ave price/unit cost (Ave price/unit cost	Syphons Bulbs
3	UK Industry	Ave price	(Sawing & cutting m/cs (Pumps, (passenger cars.

4. Results (see Table)

The results given in 4.1 - 4.6 are from aggregation of all results from data sets given in 3.2, giving equal weight to each series. It is possible that more weight should be given to either more relevant data, e.g. arc welding equipment industry data, or to more reliable data, e.g. Sparklets data. However there is little basis for evaluation of combinations of relevance and reliability.

Results from aggregation of all series from arc welding equipment industries of countries are given in 4.7.

Although results from countries are slightly different from those for all sets of data, the conclusions which may be drawn are the same.

4.1 In all but one case at least one variable was significantly correlated with average price or cost per unit.

4.2 However, in almost half of these cases, each of the three variables were significant.

4.3 Overall, variables volume and cumulative output are each best in twice as many cases as is time.

4.4 Penalties of using;

a) One uniform variable throughout for the model (whether time, volume or cumulative output) over

b) Choosing the best variable for each case. Measured by the percentage worsening of error of fit.

	Time	Volume	Cumulative output
Ave % Worsening of error	24% (max 101%)	45% (max 280%)	23% (max 102%)

4.5 The Log/log model was better than the linear model in two-thirds of the cases.

4.6 In approximately one sixth of the cases inclusion of a further variable improved the model.

4.7 Results from the nine data sets of arc welding equipment industries of all countries.

a) In one case (Japan arc welding machines 1948-70) there is no correlation between unit price and any of the variables.

b) In only two cases were each of the three variables significant.

c) Each variable is significant in approximately one third of the cases.

d) Again, the log/log model is better than linear or log/linear in two-thirds of the cases.

e) Percentage worsening if uniform variable is chosen over the best in each case.

Time	Volume	Cumulative output
15% (max 101%)	49% (max 128%)	15% (max 102%)

4.8 Experience curve 'slopes' (percentage price of unit cost ratio over a doubling of cumulative output) varied widely:

a) Between 61% and 123% for products

b) Between 24% and 161% for arc welding equipment industries of different countries.

Some of this variation could be due to errors in estimation of cumulative output at the start of the period.

For examples see appendix.

4.9 For BOC AE, the best model for unit cost is a log/log relationship with volume.

Choice of volume reduces error of fit by an average of 33% over the other variables.

Choice of the log/log model reduces error of fit by 4%.- 6% over linear or log/linear. (For independent variables volume or cumulative output)

4.10 However, confidence limits for this model depend on correct prediction of output volumes over the period of prediction.

4.11 Prediction of volumes at BOC AE may be subject to error. NB. Compound growth rate denoted by c.g.rate.

e.g.	Actual c.g. rate	Predicted c.g. rate	Error in volume after 5 years
	10% p.a.	5% p.a.	-21%
	10% p.a.	20% p.a.	+55%

4.12 Effect of errors in predicted volumes on confidence limits for predicted unit costs at BOC AE after 5 years, assuming 10% p.a. c.g. rate is correct.

	Errors in volume prediction	% Confidence Limits		
		Time	Vol	Cum output
a)	None (ie 10% p.a. correctly predicted	-27 to +37	-22 to +28	-26 to +35
b)	± 10% error	"	-25 to +34	-26 to +36
c)	± 20% error	"	-28 to +41	-27 to +37
d)	± 30%	"	-31 to +50	-27.5 to +38
e)	± 40%	"	-33 to +62	-28 to +38
f)	± 50%	"	-35 to +79	-28 to +39

4.13 Prediction of average price of a rectifier from UK industry data.

The best model using one variable is a linear relationship with cumulative output.

Choice of cumulative output reduces the error of fit by an average 15% over time or volume.

Using cumulative output, choice of a log model reduces the error of fit by 13% over log/log, and 12% over log/linear.

4.14 % Confidence limits for UK average price, after a 5 year period, assuming c.g. rate (linear model).

Time	Volume	Cum Output
-27 to +37	-35 to +54	-28 to +40

4.15 Several radically differing trends in price movements were discovered in data covering long periods of time. (For examples see appendix).

4.16 These generally coincide with changes in rate of volume growth.

4.17 However, there is no consistent pattern of price rises or declines coinciding with particular periods of growth.

4.18 For BOC Arc Equipment, all cost reduction occured in fixed costs per unit, with no significant reduction to be found in direct cost per unit.

4.19 Since 1970, BOC Arc Equipment unit costs have risen by 4.8% whereas BOC AE unit prices fell by 19%, and UK industry average prices fell by 35%.

5. Organisational observations

5.1 Pricing policy at BOC AE.

The present pricing procedure combines contribution targets and knowledge of market prices within constraints set by the price commission

Apparently there is little formal prediction of likely effects of any change in prices. There appears to be a need in BOC AE for an optional pricing policy combining:

Factors

a) Current industry prices

b) Future industry prices

c) Current BOC AE costs

d) Future BOC AE costs and sensitivity to volume prediction

e) Sensitivity of demand to price

(State of research on (a) to (e) in differing stages)

Criteria

a) Survival

b) Profit

5.2 Current uses for a model for unit cost/price at BOC AE.

a) Use of predicted future price reduction in the industry to target unit cost reduction at BOC AE.

b) Use of predicted future unit cost reduction in BOC AE to compare target.

c) For analysis of current and potential future positions of BOC AE with respect to the industry, as an input to strategic planning decisions.

6. Conclusions (reference to numbered results)

6.1 In the absence of other factors, choice of a model for predicting unit cost or price should be the best fitting model for each series predicted. (4.1 - 4.7)

6.2 If the model selected is a log/log relationship with cumulative output (ie. 'experience curve'), then the slope of the curve must be calculated for each series. (4.8)

6.3 The best model for predicting unit cost at BOC is a log/log model, but choice of the variable depends on the accuracy of volume predictions.

Accuracy of volume prediction by end of 5 years	Best variable
up to ± 10%	Volume
± 10 - 20%	Little to choose between all three
Over ± 20%	Time
	(4.9 - 4.12)

6.4 The best model for predicting average price from UK industry data is a linear model relating average price to cumulative output. (4.13)

6.5 Any model chosen may be an unreliable predictor of price or unit cost in the event of major changes in the rate of volume growth. (4.15 - 4.17)

6.6 In BOC AE the lack of unit cost reduction over the last eight years indicates that in the past, attempts to 'go down' the experience curve by accumulating cumulative output have not been accompanied by management of unit costs. (4.19)

6.7 There is no evidence that a cause and effect relationship has existed between cumulative output and unit cost for BOC AE. (6.3, 6.6)

6.8 There is little evidence that this relationship exists in the arc welding equipment industry in general. (4.7, 4.15)

6.9 At the present state of research, there is no indication that a sudden change in cumulative output, e.g. by acquisition, or a sudden change in scale of operations will necessarily result in unit cost reduction, particularly for BOC AE. (6.5, 6.7)

6.10 Future survival will depend on the control and monitoring of unit cost. (6.6 - 6.9)

6.11 The choice of forecasting method is relatively trivial compared with the accomplishments of 6.10.

6.12 To reduce unit costs, major alternatives for BOC AE are:

a) Reduce fixed costs

b) Improve performance in cutting direct cost per unit

c) Increase sales volumes with control of fixed costs. (4.9,4.18)

7. Possible future work required in BOC AE

7.1 Continue to research price and cost trends particularly for BOC and UK.

7.2 Further work on forecasting accuracy of the model including investigation of inaccuracy of forecasts of output volume from past data.

7.3 Reduction of unit cost either by:

a) Increasing volume of sales

b) Cutting fixed costs

c) Improved direct cost reduction

7.4 Outline procedures to incorporate the best forecasts of industry price and BOC unit cost into the strategic planning process, for evaluation of planned changes.

7.5 The setting up of a procedure for monitoring unit cost against targets.

7.6 Construct a price setting model incorporating both work to date and the current market research on sensitivity of demand to price.

Appendix H

Analysis of fixed costs of Boc Arc Equipment

1965/66 to 1977/78

Index

Index of Tables

Index of Graphs

Appendix H.

Analysis of fixed costs of Boc Arc Equipment 1965/66 to 1977/78

1. Data and adjustments

Data for 1977/78 has been added to data previously obtained for 1965/66 to 1976/77 (Appendix C.3)

1.1. Cost data

Source: Records of annual trading results from documents A-11 and predecessors. Annual profit and loss accounts from HWR.

Cost data includes that for home, export and OEM sales, and covers costs of MIG, TIG and DC MANUAL and PLASMA.

Costs include those for parts and service. A proportion covering that for AC Manual has been deducted from the total for the period 1974-78. (Proportion calculated on the basis of sales of AC Manual spares).

Costs excluded from figures used in calculations are central costs, discount received, Germany, and costs of the Machinery Centre and Machine Tool grants.

The categories of cost given in accounts, which varied over the whole period, could be allocated into five main types:

a) Manufacturing and distribution (including operations and carriage).

b) Marketing (includes marketing, export and warranty). Marketing costs for 1975 onwards were adjusted to compensate for the transfer of the selling function to Boc Gases division. (Appendix C 3.2.3. (f)).

c) Publicity

d) Research and development

e) Other - including administration, etc.

1.2. Annual volume of output

The source of this data was the records of production schedules at HWR (Appendix C.3.2.1.)

1.3. Amalgamation of data for Boc and HWR

As in previous work, data for costs incurred at HWR for the period preceding amalgamation of the two companies (i.e. 1966-72), has been added to that for Boc AE, to give a consistent picture for the whole business. (Appendix C.3.2.4.)

2. Methods of analysis

After adjusting the data for 1977/78 and adding it to previous data (Tables H.1 and H.2), costs were analysed in the following way:

a) Proportions of the total were calculated for each category of fixed costs for each year (Table H.3)

b) This proportion, for each type of cost, was tested for significant trends over the period 1966-78.

c) Average compound growth rates were calculated for the proportion formed by each type of cost.

d) Annual cost data was deflated using the index of Home sales of all manufactured goods, to 1978 values, (i.e. 1978 = 100), and divided by annual volume of output to give cost per unit. This data was used to look at any trends in the composition of total product cost.

3. <u>Results (Tables H.5 and H.6)</u>

a) The proportion of the total fixed costs formed by manufacturing costs has declined over the period in question, at a rate of approximately 3% p.a. Forming approximately 20% of total unit product cost in 1965/66, it formed only 13% by 1977/78.

b) Marketing costs had risen as a proportion of fixed costs, at approximately 4% p.a., forming 10% of total unit product cost by 1978.

c) Publicity cost/unit remained at a steady 1-2% of total unit cost.

d) The proportion of costs spent on R and D showed the greatest decline. In 1978 it formed only 4% of total unit product cost, as against 11% in 1966.

e) "Other" costs, mainly administration, had risen as a proportion of total fixed costs, at a rate of 13% p.a., forming 9% of total unit product cost by 1978.

f) It must be noted that all costs per unit rose during 1977/78, with the highest rises being in direct costs, manufacturing, publicity and administration.

4. Conclusions

The composition of fixed costs had changed over the period 1966-78, with relative increases in marketing and administration costs, decline in R and D expenditure, and a slight decline in marketing costs.

All elements of product cost rose in 1977/78, with highest rises being in direct costs, manufacturing, publicity and administration.

Table H.1

Raw Data for 1977/78

Source - A-11 record of trading results.

		£'000
SALES	MIG	2695
	TIG	2171
	PLASMA	244
	MANUAL	1523
	PARTS	1709
	SERVICE	266
	TOTAL	8608
CONTRIBUTION	MIG	764
	TIG	872
	PLASMA	41
	MANUAL	294
	PARTS	795
	SERVICE	70
		2836
FIXED COSTS	MIG	1022
	TIG	764
	PLASMA	88
	MANUAL	498
	PARTS	573
	SERVICE	66
		3011
TRADING LOSS		175

Volume of output (from production records)

MIG	1886
TIG & PLAS	1531
TOTAL	3417

Adjustments to data for 1977/78

Index: Home sales of all manufactured goods, 289.3 (1970 = 100)

Fixed costs, omitting central costs, machining centre, Gemav and discounts received.

	Manuf. & Distrib.	Marketing	Publicity	R & D	Other	Total
			Costs £'000			
MIG	375	110	76	148	212	921
TIG	304	95	15	87	171	672
PLASMA	34	11	2	13	19	79
PARTS – MIG TIG & PLASMA	231	10	12	47	191	491
(– MANUAL	7	1	–	1	6	15
SERVICE	–	–	–	–	60	60
TOTAL (Excl. MANUAL)	944	226	105	295	653	2223

Adjustment to marketing costs to compensate for removal of selling function to gases division (1974 onwards)

Amount to be added £137 (at 1970 value)

(See Appendix C, 4.2.3. (f))

= £396

Hence, total marketing costs at 1978 value estimated to be

£226 + 396 = £622.

Total fixed costs for 1977/78 at 1978 value

is £2223 + 396 = £2619

Table H.3

Data on the breakdown of fixed costs at Doc Arc Equipment

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78
	Annual costs £'000 (Actual value, adjusted)												
Manuf. and distrib.	292	307	334	398	383	419	431	496	532	623	587	668	944
Marketing	100	125	215	232	224	269	282	322	328	479	566	663	622
Publicity	17	10	14	17	14	39	28	48	19	70	49	48	105
R & D	176	159	146	164	109	122	113	155	210	259	236	274	295
Other	35	77	79	53	82	67	64	154	292	190	411	477	653
Total	620	678	788	864	817	916	918	1175	1381	1621	1849	2130	2619
	Annual costs £'000 (Deflated)												
Manuf. and distrib.	341	355	371	426	383	384	375	403	350	330	269	259	326
Marketing	117	144	239	248	224	247	246	261	216	254	259	256	215
Publicity	20	12	16	18	14	36	24	39	12	37	22	19	36
R & D	205	184	162	176	109	112	98	126	138	137	108	106	102
Other	41	89	88	57	82	61	56	125	192	101	188	185	226
Total	724	784	876	925	817	840	799	954	908	859	845	825	905
	Proportion formed by each category												
Manuf. and distrib.	.47	.45	.42	.46	.48	.46	.47	.42	.39	.38	.32	.31	.36
Marketing	.16	.18	.27	.27	.27	.30	.31	.28	.24	.30	.31	.31	.24
Publicity	.03	.02	.02	.02	.02	.04	.03	.04	.01	.04	.02	.02	.04
R & D	.28	.24	.19	.19	.13	.13	.12	.13	.15	.16	.13	.13	.11
Other	.06	.11	.10	.06	.10	.07	.07	.13	.21	.12	.22	.23	.25

Table H.4

Analysis of total unit cost.

	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78
					Total costs £'000 (1978 value)								
Index (1978=100)	29.6	29.9	31.1	32.3	34.6	37.7	39.7	42.6	52.5	65.2	75.6	89.3	100
Direct cost	3139	2552	2739	3025	3098	2979	2920	4125	4394	3839	3688	4563	4543
Fixed costs:													
Manuf. and distrib.	986	1027	1074	1232	1121	1111	1086	1164	1014	956	776	748	944
Marketing	338	418	691	718	647	713	710	756	625	735	749	742	622
Publicity	57	33	45	53	41	103	70	113	36	107	65	54	105
R & D	595	532	470	508	315	324	285	364	400	397	312	307	295
Other	118	257	254	164	237	178	161	361	556	291	544	534	653
Total fixed	2094	2267	2534	2675	2361	2429	2312	2758	2631	2486	2446	2385	2619
TOTAL	5233	4819	5273	5700	5459	5408	5232	6883	7025	6325	6134	6948	7162
Nos. produced	2538	2378	3148	3653	3681	3335	3187	3650	4842	4132	3960	4461	3417
					Cost per unit £ (at 1978 values)								
Direct cost	1237	1073	870	828	842	893	916	1130	908	929	932	1023	1330
Fixed costs:													
Manuf. and distrib.	389	432	341	337	304	333	341	319	209	231	196	168	276
Marketing	133	175	220	197	176	214	223	207	129	178	189	166	182
Publicity	22	14	14	14	11	31	22	31	7	26	16	12	31
R & D	234	224	149	139	86	97	89	100	83	96	79	69	86
Other	47	108	81	45	64	54	51	99	115	71	137	120	191
Total fixed	825	953	805	732	641	729	726	756	543	602	617	535	766
Total unit cost	2062	2026	1675	1560	1483	1622	1642	1886	1451	1531	1549	1558	2096

Trends in the proportion formed by each type of fixed cost

Type of cost (Proportion)	Equation	Sig. level	Ave c.g. rate
Manufacturing cost/unit	$y = 1.362 - 0.0132x$	99.8%	- 3.24% p.a.
Marketing cost/unit	$y = -0.448 + 0.0100x$	99.4%	+ 3.88% p.a.
Publicity cost/unit	$y = 0.00300 + 0.000070x$	Not sig. at 95%	-
R & D cost/unit	$y = +0.867 - 0.0099x$	96.0%	- 6.71% p.a.
'Other' cost/unit	$y = -0.810 + 0.0130x$	99.6%	+ 13.4% p.a.

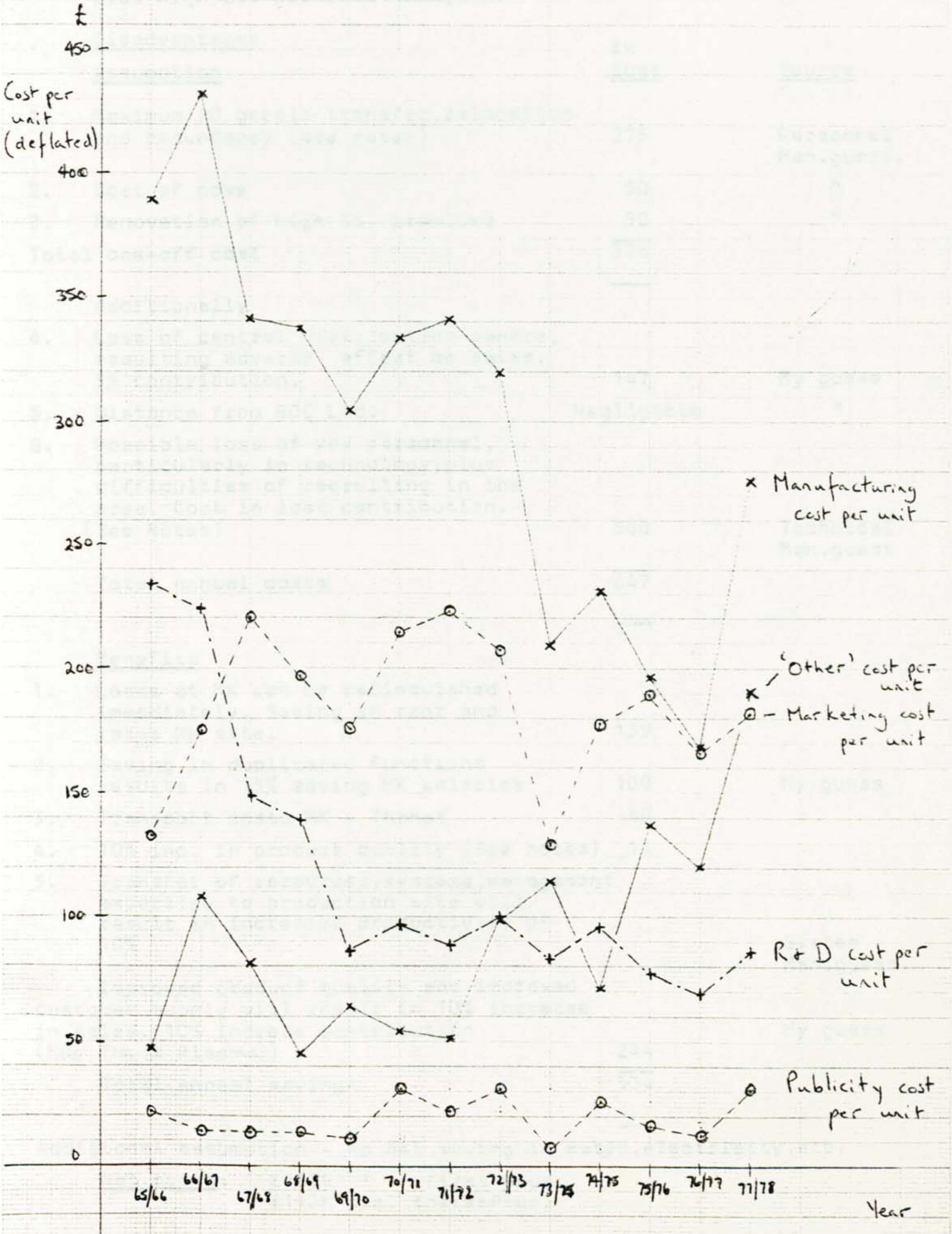
Table H.6

Results

Percentage composition of total unit cost

Type of cost	1965/66	66/67	67/68	68/69	69/70	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78
DIRECT													
Cost/unit	.60	.53	.52	.53	.57	.55	.56	.60	.62	.61	.60	.65	.63
Manuf. Cost/unit	.19	.21	.20	.22	.20	.21	.21	.17	.14	.15	.13	.11	.13
Marketing	.07	.09	.13	.12	.12	.13	.14	.11	.09	.12	.12	.11	.09
Publicity	.01	.01	.01	.01	.01	.02	.01	.02	.01	.02	.01	.01	.02
R & D	.11	.11	.09	.09	.06	.06	.05	.05	.06	.06	.05	.04	.04
Other	.02	.05	.05	.03	.04	.03	.03	.05	.08	.04	.09	.08	.09
Total fixed	.40	.47	.48	.47	.43	.45	.44	.40	.38	.39	.40	.35	.37

Graph H.1 Fixed costs per unit over the period 1965/66-1977/78



Source - see Appendix H.1

APPENDIX I

Cost saving ideas

I 1. Combine the MK site and Thanet production site using Thanet, plus High St. premises Ramsgate.

Disadvantages

	Assumption	£k Cost	Source
1.	Maximum 20 people transfer, relocation and redundancy (see notes)	275	Personnel Man. guess.
2.	Cost of move	50	"
3.	Renovation of High St. premises	50	"
Total one-off cost		375	
	Additionally		
4.	Loss of central distribution centre, resulting adverse effect on sales. 5% contribution.	147	My guess
5.	Distance from BOC Ltd.	Negligable	"
6.	Possible loss of key personnel, particularly in technology, plus difficulties of recruiting in the area. Cost in lost contribution. (See Notes)	500	Technical Man. guess
	Total annual costs	647	

Benefits

1.	Lease at MK can be relinquished immediately. Saving in rent and rates MK site.	139	
2.	Saving in duplicated functions. results in 15% saving MK salaries	100	My guess
3.	Transport costs MK - Thanet	40	
4.	10% inc. in product quality (See notes)	11	
5.	Transfer of resources, systems, management expertise to production site will result in increased productivity of 10%		System Man. guess.
	Improved product quality and improved customer supply will result in 10% increase in sales. 10% increas contribution (MIG, TIG. & Plasma)	244	My guess
	Total annual savings	534	

Additional assumption - no net saving in water, electricity, etc.

Net costs: £488k ' first year
£113K p.a. thereafter.

I 2. Combining two sites at MK

Disadvantages and costs

	Assumptions	£k Cost	Source
1.	6 months loss of production due to dislocation. Loss of contribn.	1222	Personnel Man.guess
2.	Max. 20 people transfer, relocation and redundancy (See notes)	385	"
3.	Cost of more + installation of Machines	150	"
	Total one-off costs	1757	
4.	Further building at MK site is possible and will be financed by MK development corporation. Requirement would be for further 50% space. Increased rent & rates	70 p.a.	
5.	Effect of disruption on customers will produce further 5% reduction in contribution over following 2 yrs.	122 p.a.	My guess
	Cost p.a. for 2 years.	192 p.a.	

	Benefits and Savings	£k	
1.	Sale of factory at Thanet (1 off)	2000	(one-off)
2.	Saving of rates at Thanet (Annual)	25	
3.	Transport costs MK - Thanet	40	
4.	Same increase in productivity and sales as in scheme (1)	244	
5.	Saving in salaries as in scheme (1)	100	
	Total saving p.a.	409 p.a.	

Additional assumption - No net saving in water, electricity, etc.

Net saving in first year	£582 k
Net savings next two years	£217 k
Net savings thereafter	£339 k p.a.

I 3. Thanet site used as distribution centre - i.e. no goods pass through MK. Parts are stored at Thanet, shipped direct to super branches.

Disadvantages and Costs	Cost	Source
Assumption		
1. The functions of supply, buying, inspection warehouse, quality, export all more to Thanet (40 people at present) Maximum 5 people transfer Cost of relocation, redundancy	65	
2. Cost of move	20	
3. Renovation High St. premises	50	
Total one-off costs	135k.	
Plus		
4. Loss of central distribution centre		
5. Control of supply for removed from MK management		
6. Loss of interface between marketing and supply and between marketing and the product.		
(4), (5) & (6) result in loss of 5% contribution	122k p.a.	My guess
Benefits and savings		
1. Duplication of functions results in 15% saving in salaries (see notes)	27	My guess
2. Increased communication results in 5% imp. in product supply 5% inc. in contribution	122k	My guess
3. 10% increase in product quality as in scheme (1) results in saving in warranty	11k	Quality Man. guess
Total saving p.a.	160k	
Net cost 1st year	£ 97k	
Net saving subsequent years	£ 38k p.a.	

I 4. Moving inspection function to Thanet; inspection function at MK will only be for visual damage.

	Disadvantages and costs	£k Cost	Source
1.	Requirements for 4 inspectors at Thanet	10k p.a.	My guess
2.	Loss of control of quality at MK.	Negligable	
	Benefits and savings		
1.	Saving of 2 inspectors at MK	5k p.a.	Quality Man.guess
2.	Feedback to product quality improves quality by 10% Saving in warranty costs.	11k p.a.	
3.	Effect of improved product quality on sales say 2% inc.contribution	49k p.a.	
	Total savings	65k p.a.	
	Net annual savings	£ 55k p.a.	

I 5. Moving development function to Thanet (a) Assuming permanent dislocation to development function

	Disadvantages and Costs Assumption	£k Cost	Source
1.	75% technical development staff would not move. Recruitment of staff difficult in the area. May well result in abandonment of cost reduction design programme. Loss in unachieved contribution after 2 years.	500k p.a.	Technical Man.guess
2.	Cost of personnel relocation and redundancy	39k one off.	"
3.	Cost of move	10k " "	My guess
	Total one-off costs	49k	
	Annual cost after 2 years	500k p.a.	

Benefits and savings		£k Cost
1.	75% salaries of technical dept. (assumption £5000 p.a. average salary.	75k
	Net Saving : 1st year	26k
	2nd year	75k
	Net cost : after 2 years	425k

(b) Assuming development function continues.

	Disadvantages and costs	£k
1.	Continuation of recruitment by payment of large salaries. Say £7500 p.a. Increased cost 15 x £2500	37.5 p.a.
2.	Relocation redundancies as above	39 One off
3.	Cost of move	10 One off

Benefits and savings

1. Increased liason with design, industrial engineering and product would reduce slip in project management by 2 months in 18 months.
Estimated saving due to earlier launches

One-off inc. contribution 1982. £ 250k

Net Cost	1st year	£ 86.5k
Net Cost	2nd year	£ 37.5k
Net saving	3rd year (one-off)	£212.5k
Net Cost	thereafter	£ 37.5k p.a.

I 6. Design of family of products based on common components

Assumptions

Taken from Hemingford Workshop report Jan.1979.

(a) No increase in present resources.

(b) Further 15% reduction in costs.

Results : Delay to new product development programme, no increased contribution, loss of £180k incurred through curtailment of robot development

(c) Recruitment to second reforecast. (for costs see table)

Results : No curtailment of robot development, new product development programme produces £250k additional contribution by 1982.

(d) Recruitment to original budget returned in 1980

Results : No curtailment of robot development, next product development programme produces £400k additional contribution by 1982.

Cost and savings for alternatives (b) (c) & (d) compared with status quo (a)

		£k			
a.	Continuation of present resources	1978/79	1979/80	1980/81	Total
	Resource costs	150	150	150	450
	Extra contribution 1982				None
b.	10% reduction in costs				
	Resource costs	135	135	135	405
	Cost of loss due to robot work				180
	Savings due to extra contribution				None
	loss				180
	Savings in resources				45
	Net Loss				135
c.	Recruitment to 2nd forecast				
	Resource costs	150	210	240	600
	Extra cost of resources				150
	Savings due to extra contributions				250
	Net savings				100
d.	Recruitment to original budget				
	Resource costs	150	250	250	650
	Extra cost of resources				200
	Savings from extra contbn.				400
	Net savings				200

I 7. Design change for cost reduction to present models.

Assumption

1. The suggestions and ideas for reduction of direct costs (at present not implemented due to the inadequacy of the system of resources) could be evaluated and implemented by at the most:

   A team of 10 people spending 1 day per week.

2. Resulting cost reduction would form 10 - 15% of direct cost.

Cost	People : 10 x £5000 x 1/5	£10,k p.a.
Saving	10% direct cost of items manufactured at Thanet	£268,k p.a.
Net Saving		£258,k p.a.

I 8. Definition of areas of responsibility and accountability for actions, lines of communication.

Assumptions

1. The task will require one person to organise, plus 1 week's time from each member of personnel (Say p.a. to allow for charges)
2. The resulting improvement in decision making, action taking, communication etc will result in a 5% increase in productivity, or decrease in fixed costs.

Cost	Person to organise (+ overheads)	£10,000 p.a.
	1 week of each persons time 1/52 x £800,000	16,000 p.a.
		£26,000 p.a.
Saving	5% x 2133	£106,650 p.a.
Net saving		£ 80,650 p.a

I 9. Systems at Thanet.

a. Introducing MAPEX as replacement for PRINCE for production control and scheduling.

Assumptions

a. Installation requires only the extra resource of one O & M man.

b. MAPEX will reduce stock and WIP by 20%

c. Increase in output volumes of 10% (Identification of bottlenecks, production reprogrammed instantly to allow for shortages; produces more continuity of production flow).

Cost Introduction of new system 6k p.a.

Saving Saving on rental of MAPEX over PRINCE 10k p.a.
Saving on Stock and WIP

Saving on buying

Advantage MAPEX has additional advantage of potential for development of further production systems.

Disadvantage Recruitment of suitable personnel may be difficult in the area.

b. Improvement of general system at Thanet.

Assumption Identification of area of responsibility, lines of communication, flow of information etc will produce greater efficiency resulting in potential for 10% saving in admin. personnel.

Cost System development say £10k p.a. for 2 years

Saving 10% admin. salaries at Thanet £25k p.a.

Net Saving : £15k pa. for 2 years

£25k pa. thereafter

Advantage Sorting out the systems should also help to strengthen middle management by definition of tasks and lines of communication.

10a) Systems at MK

Assumption 10 - 15% saving in salaries/costs would be achieved from the following:

a. Automatic efficient flow of paper round the site
b. Eliminate unnecessary reports, use present computer facilities to greater advantage.

c. Put in word-processors etc in areas where multi-copies of documents are produced.

Cost (one-off)

Personnel:	1 senior programmer) 1 analyst)	2 years at £10k p.a. £20k
Development and hardware costs		£10k
Total costs (one-off)		£30k

Saving (after 2 years)

At 10% x salaries MK	£89k p.a.
Net Cost First 2 years total	£30k
Saving after 2 years	£89k p.a.

I 10 b) Specific systems attention to export office and paperwork.

Assumption : Improvement of paperwork system plus a word processor producing multiple copy documents plus a file for input to computer, will save 10 - 15% cost of export sales (Say after 1 year)

Cost (One-off)	Hardware	£5000
	Support	2000
		£7000
Saving (After 1 year)		£6000 p.a.
i.e. Net Cost	1st year	£7k
Net Savings	thereafter	£6k p.a.

I 11. Stock policy system and supplier analysis for buying at Thanet.

Assumption : 6 months development costs using present computer facilities at Thanet would save 2% on materials costs.

Cost (One-off)		£5000
Saving (say after 1 year)		£45000
i.e. Net Cost	1st year	£5k
Net Saving	thereafter	£45k p.a.

I 12. Change part numbering to BRISH system to aid stadardisation of components.

Assumption : Prevention of part no. duplication and resulting difficulties.

Cost 2 personnel for 2½ years	£25k
Consultants fees	£ 5k
Total cost (One-off) Over 2 years	£30k

Saving (after 2 years)

I 13. Machine tool support for special products.

Assumption : In house machine tools will save time in putting work out or in doing work by hand. Increased productivity as a result estimated at 20%

Cost (One-off)		£2500
Saving in inc. contribution (25% x £25000)		£6250
i.e. Net Saving	first year	£3750
Saving subsequent years		£6250 p.a.

I 14. <u>Export commission agents.</u>

Distributors in the Far East are appointed by BOC Sales personnel from Cricklewood and paid commission by BOC AE for any sales made in their territories.

It is estimated that 30% of these are defunct and contribute nothing to these sales.

<u>Assumption</u> : The time taken to sort out defunct distributors would be minimal if BOC sales people report them as and when discovered.

<u>Cost</u> Minimal

<u>Saving</u> 30% x £22000 = £6600 p.a.

I 15. <u>Increased clerical assistance at MK</u>.

a. At present the planned programme for an improvement in quality to save 11.5k p.a. in warranty costs is taking 1 year instead of 6 months.

<u>Assumption</u> : 1) Further such programmes will follow,
2) Help in typing, answering phone and statistical analysis of faults will restore the programme to its original schedule.

<u>Cost</u> 1 person + overheads. £3500 p.a.

<u>Saving</u> Warranty costs £5000 p.a.

<u>Net Saving</u> £1500 p.a.

<u>Advantages</u> 1) Increased customer satisfaction.
2) Feedback to service engineers - information on faults, type, and progress on correction.

b. A junior for dealing with despatches in publicity, 1½ - 2 days per week.

<u>Assumption</u> : The two days per week of the publicity managers time could be used to do his own layouts, at present done externally.

<u>Cost</u> 2/5 x £2500 £1000 p.a.

<u>Saving</u> £1400 -1600 p.a.

i.e. <u>Net Saving</u> £400-600 p.a.

I 16. <u>Increased clerical assistance at Thanet</u>.

a. To be shared by design and industrial engineering department.

<u>Net saving</u> £2340 p.a.
£45 per week)

b. In account department, to enable cost accountant to investigate overhead costs and implementation of cost saving ideas. e.g. Economic order quantities etc, hire of heaters, cost of small repair jobs, etc.

<u>Cost</u> (1 person) £3000 p.a.

<u>Saving</u> Say 5% x £76000 (See notes) £3800 p.a.

<u>Net Saving</u> 1st year say £400

<u>Net Saving</u> thereafter £800 p.a.

I 17. Increased labouring help.

a. In inspection 2 hrs pwe week tidying, cleaning, etc.

Assumption : At presemt 4 inspectors stop work ½ hr. early Friday to tidy up, work which could be done by e.g. O.A.P.

Cost at	£2 per week	£104 p.a.
Save	£5 a week	£260 p.a.
Net saving		£156 p.a.

b. This function (a) could possibly be combined with the labouring help needed in the labs as part of resourse requirements of the technical dept.

I 18. Setting-up of in house packing punction for warehouse and export packing.

Assumption : The packing function could be set up on site (warehouse people think there is sufficient space), and would require further 5 personnel, (see notes) and an overhead crane.

Cost	Additional personnel	£20,000 p.a.
	Stock of	1,000
	Overhead crane (one-off)	7,000

Total Annual £21k p.a. One off £7k

Saving Packing charges (external) £38k p.a.

Net Saving £10 in first year

Thereafter £18k p.a.

Advantage : Greater control over deliveries and quality of delivered goods.

Disadvantages : Packing punction will take up space, and will be an additional function for which we have no present skill and hence could well be mismanaged.

I 19. Scrap added value scheme.

Assumption :

1. The scheme takes the accountant 3 days per week to calculate added value, and committee meetings take 10 people 1 day per month.
2. Incentive value for increased productivity fairly low.

Cost Nil

Saving 15% accountants time say £600 p.a.
10 people 1 day per month £2500 p.a.

Net Saving £3100 p a.

Disadvantage There is felt to be overall advantage for the company from a selection of personnel from all departments meeting once a month to discuss the success or otherwise of the business and what may affect it. This is felt to compensate for the costs.

I 20. Comminications

a. Postage - tightening up on postal system e.g. Communal envelopes for all branches (only 2 or 3 at present)

Cost - minimal.

Saving - £30 - £40 p. week. £1500-2000 p.a.

b. Phones - tightening up on useage of phone in the morning, be lessening the number of phones with no bar on mornings.

Cost - minimal.

Saving est. 10% x phone bill say £5000 p.a.

I 21. Shipping direct to Europe from Thanet, to all Benelux countries, Socome, Smitweld etc.

Disadvantages and costs.

1. Requirement for shipping at Thanet.

2 people + overheads	cost		£10k p.a.
2. Loss of control from MK, processing of orders etc. Loss say 5% contbn. from export.	say		£52k p.a.
Total			£62k p.a.

Benefits and savings.

1. Cutting down on cost of shipping to MK. and back.

Proportion of machines $\frac{80\text{-}90}{375}$ p. month i.e. 21 x £40k £8.5k p.a.

i.e. Net Cost : £53.kk p.a.

Ideas as yet unevaluated

1. Resources

1.1 A test engineer at Thanet for detemining test procedures for reliability in the field. This would cut down on cost of testing, breakdown, warranty costs etc.

1.2 More clerical back-up for Thanet in general, particularly investigation of micro-computer for storeage and access of data; this would save time of personnel, and help communicate with Thanet.

1.3 Stationery and Rank Xerox machine - have in one unit under control of qualified Xerox operator. Save

a. On down time of machine
b. Time wasted for people doing photocopying/waiting

1.4 Possibility of forming most of remaining secretaries into pool?

2. Communication and information flow.

2.1 Communication both interdepartmental and baard-operational level is generally bad.
This is a result of inadequate definition of areas of responsibility and accountability, and results in poor decision making, duplication of effort, hoarding of information in departments, etc.

2.2 Communication of actions is also bad. More secretarial help would give better communication.

2.3 Meetings should be better organised, and constructive. Some meetings are duplicated (e.g. in Technical dept.)

2.4 There could be a flow of information from service dept → marketing, if marketing would pay for it.

2.5 Information available - could this not be catalogued and made known generally? (e.g. duplication technical and buying) More comprehensive library to save time searching for technical information.

2.6 Another tie-line to Thanet. (Cost £2½k p.a.)

3. Design office -

3.1 Why doesn't the drawing office draw in pencil on film, to save time when making charges.

3.2 Instead of having assembly drawing and parts list, why not have parts list <u>on</u> drawing. This would save time,paper,and storage space.

3.3 Design basic product and extras rather than wide variety of products.

3.4 Too many stick-on labels on machines.

3.5 Too many terminal blocks - cost of cutting wores,blocks,metal for bolting onto etc.

3.6 Present procedure for drawings and prints at Thanet does not work properly, end up with people working to different drawings. Need master drawing and issue of prints when necessary.

4. <u>Operational</u>.

4.1 Segregation of slow-moving goods in the warehouse so that the impact is visual. Then cope with slow-moving stock and try to eliminate it.

4.2 Vet supplies for 'total cost' of purchases including cost of checking, sending back etc.

4.3 End of month rush - causes friction at all levels and eventually increase in computer costs as reports have to be run at uneconomic rates. Also late invoices are posted manually (3 girls for 1½ days)

4.4 Computer hardware; why not change to other maintenance organisations which are cheaper and more effective, to reduce downtime.

4.5 There should be more control over the ability to purchase <u>anything</u> - e.g. furniture etc.

4.6 Price lists - why not have part no. and price on same page, to save looking everything up twice.

4.7 Export quality - why not mark inspected machines by a bag of a different colour, e.g. red, then would be instantly recognised.
Results: Easier marshalling of consignments.
: Spot check on total of 'red covers' in a consignment.

4.8 Have suspended furniture and planned space in open plan office area for saving space and cost, this would function far more efficiently as everything is to hand.

4.9 Availability of stock for export: at present checked manually by going to parts, but no way, of checking priorities or changing them. Need VDU - computer.

4.10 Ensure batch quantities economically optional for Thanet production.

4.11 Standards system gives <u>no measure of efficient buying</u>. Should have standard/actual by feeding invoices into computer and updating last buying price.

4.12 Stringent budgets and budget control, at levels over which people have responsibility.

4.13 Salaries at present done by Personnel dept. at Thanet, always late for end of month. Why don't accounts do it?

5. <u>Morale</u>

5.1 Commsnication on the place of A.E. in BOC Ltd., how important AE is, with explanation of the requirements of BOC Ltd on the company. This will give motivation and identity and the feeling of pulling together.

5.2 When disposing of company cars, why not offer it first to staff as a perk?

5.3 Suggestions scheme with reward panel to evaluate ideas.

Appendix J

Analysis of contribution by products, and the relationship between price, volume and contribution

Index:

Index of Tables

Appendix J. Analysis of contribution by products and the relationship between price, volume and contribution

The first stage of this analysis consists of the analysis of contribution figures for 1977/78 to find out which of the MIG and TIG products have produced the most contribution, and, if these are ranked by the amount they produce, how much is produced by the top ten items in each process.

Again the data was the greatest problem, with different sources giving different volumes of sales (see J.1). Eventually the analysis was done from two computer tabulations, with the top ten items picked out by hand (see J.2.)

The figures obtained were then used to examine the relationship between price, sales volume and contribution levels. Under the assumption that the market is price sensitive and a reduction in price would bring an increase in volume of sales, the marketing manager wished to know how much of an increase would be required in order to maintain contribution levels. The results are given in J.3.

J.1. Discrepancies between data from different sources

Originally figures for volumes of each major item sold in 1977/78 were produced by the product managers. However, these showed such large discrepancies when compared with volumes of production at the factory, that further investigations were made.

J.1.1. Data and methods of investigation

The main sources of data were as follows:

a) R.21, a computer tabulation compiled from orders received. These are typed directly into the computer as soon as they are received at BOC AE. The tabulation then gives monthly demand figures, divided into home and export, and uses these to produce a demand forecast for the following 12 months.

b) R.15, invoiced home sales. This is a computer tabulation produced by NAC from sales invoiced by gases division at the moment of sale, for UK sales only.

c) R05, invoiced export sales. A computer tabulation produced from the BOC AE sales ledger (all export sales are made direct from BOC AE).

d) Production volumes from the factory

e) Volumes of sales given by product managers.

A few major products were selected, and the figures for output volumes for each for 1977/78 were taken from each source and compared (Table J.1.).

Enquiries were then launched to try to determine the reasons for the discrepancies.

J.1.2. Results (See Tables J.1 and J.2)

It is endent from the table that there are large discrepancies between figures produced from different sources.

Results of the investigation of reasons or causes for these discrepancies are as follows:

a) <u>The difference between production and sales volumes</u>

Some of the difference may be accounted for by difference in stock levels at the beginning and end of the year. However, this is impossible to check since stock is only recorded by value.

Another cause of discrepancy is in the number of machines sold directly to other equipment manufacturers (OEM's), or with slight adjustment, sold as specials under a different part number. This type of discrepancy has been investigated in previous work (see Appendix C).

b) <u>The difference between orders received and invoiced sales (R21 and R15 + R05)</u>

i) The reason for this may be an increase in the size of the order book, or to an increasing amount of forward orders. (These can be anything up to 15 months in advance.)

The order book did increase over this period, but again volumes cannot be checked as figures are for value only, and also are only given for the total product group. However, the increase of £74,506 in the order book for MIG cannot account for a discrepancy of 100 TM 350 sets, at £683.20 average transfer price. (See J.1, first item.)

The increasing number of forward orders was not thought by the supply clerks to include large volumes of rectifiers.

ii) Discrepancies may also be due to delays between orders received and invoiced sales, particularly if items are ordered for stocking branches, and thus recorded as an order but not as a sale. In the case of the TM 350, the discrepancy between the amount ordered and amount sold would result in a large stock being held at the branches. This apparently was not true, so this suggestion cannot account for the discrepancies.

iii) There may have been errors in the R21. On investigating this suggestion, a potential source of errors was found. This occurs in the cancellation of orders.

If an order has not been allocated from stock, then an error in the computer program means that although the value of the order is subtracted from the total, the number of items ordered is not adjusted.

Thus, although the value of orders received and the stock position for each part number is correct, the demand volume may be in error by a considerable amount. It is this figure which is used for the R21.

iv) There may be errors in the R15 and R05. These are less likely, since both are compiled from invoiced sales and subject to checks may hash totals etc.

c) <u>Difference between volumes recorded by product managers</u>

As far as could be gathered, these figures are obtained from the R21, and are fairly similar to demand volumes obtained from this source. (See Tables J.1 and J.2.)

However, as these demand volumes are likely to be in error (see (b)(iii) above), figures based on these will equally be in error.

J.1.3. Conclusions

Since volumes recorded in the R21 as demand volumes for orders received are likely to be overstated, this is not a good source of data for this experiment. Similarly, volumes of sales recorded by product managers may be equally in error. (See J.1.2. b(iii) and (c))

Volumes of sales recorded in the R15 (UK Sales) and R05 (export sales) are less likely to be in error, and are much closer to production volumes.

The differences between recorded volumes of sales and production volumes are explicable (see J.1.2.(a)).

Hence it was decided to use the computer tabulations for invoiced sales, the R15 and R05, as a basis for the analysis of contribution by product.

J.2. Analysis of contribution by product for MIG & TIG

J.2.1. Data

Two computer tabulations were used: R15 - invoiced home sales. This is a computer tabulation produced by NAC from sales invoiced by gases division, in the UK. R05 - invoiced export sales. A computer tabulation produced from BOC AE sales ledger, since all export sales are made direct from BOC AE.

Both gave volume of sales, value, cost of sales and contribution, by part number.

J.2.2. Analysis

1.) In counting up volumes, items in packages were included. They were then costed as individual items, using the standard direct cost for that item.

2.) Items not in packages have been costed using actual direct cost where this figure is available.

3.) Autolynx has been omitted from the ranking since in 1977/78 total cost of sales of Autolynx exceeded transfer value.

4.) In the analysis of the top ten TIG items, data for a further four products has been included for comparison purposes as they were considered by the TIG product manager to be in his top ten products.

5.) The analysis gives the proportion of total BOC AE contribution for 1977/78 represented by:

MIG & TIG top ten items

MIG & TIG top ten rectifiers (five of each)

MIG & TIG top ten items plus four extra TIG items considered to be major products.

The analysis also gives the split in contribution of top ten provided by home and export sales.

J.2.3. Results

See Tables J3 - J8 for data, and J9 - J12 for analyses. The following points were made:

a) The top twenty items form approximately 40% of the total BOC AE business by contribution (See Table J.12)

b) Of these, slightly less than half is formed by the top ten MIG items (18%), slightly more than half by TIG (22%). (See Table J.12)

c) Rectifiers plus other major TIG items (TCM 450, TSM 335) form approximately 24% of total business by contribution. (See Table J.11)

	MIG	TIG	TOTAL
Rectifiers (+ major TIG items)	8%	16%	24%
Other top ten items	10%	6%	16%
Total	18%	22%	40%

Summary Table

d) Rectifiers form a larger proportion of home sales than they do of export sales.(See J.9 and J.10)

Table J.1

Comparison of numbers produced/sold

of different items from differing sources

Product	R15 + R05 (Me)	Production figs.(Jan)	Product Managers	R21(Demand History)
MIG TM350				
1198012	142			
Packages	400			
	542	470	630	641
TM 225				
1198057	71			
Packages	336			
	407	435	470 (Pkges 301)	499
Lynxpak 200				
1403811	69	53	84	72
1403812/3	23			27
	92			99
SMR 500				
10236	84	65		100
TM 600				
1198076	39	103	77	89
Packages	17			
	140	168		189
TM SPR				
1198058	41	59	38	66
Packages	22			
	63			

CONT.

Table J.1 cont. (J2)

Comparison of numbers produced/sold of different items from differing sources

Product	R15 + R05 (Me)	Production figs.(Jan)	Product Managers	R21(Demand History
TIG TT AC/DC 375				
1198009	216	206		260
1198061	123	219		297
1404064	41			
1198072	-	1		1
1198074	4	2		14
	384	428	572	572
TT DC 250				
1198005	76	75		
1198096		1		
	76	76	99	99
TA AC/DC 320				
10390	186	205		175
10400	84	84		
	270	289		
TA DC 525				
10383	147	145	165	183
10396	27	27		
	174	172		
1198050		12		
1198107		20		
	498	204		

CONT

Table J.1. cont. (J2)

Comparison of numbers produced/sold

of different items from differing sources

Product	R15 + R05 (Me)	Production figs.(Jan)	Product Managers	R21(Demand History)
	Source of information			
TA DC 150				
10391	128	175	173	154
AC 350				
1198007	28	20	36	36
1404065	1			
DC 825				
10384	38	55	33	39
1198059				
TT THF 450	295	310	255	255
TT TCM 450	110	79	126	116
TT TSM 335	116	73	119	

Table J.3

MIG - Overall top ten on transfer value

		Qty	ASP	Value	Cost	Contribn.
1)	TF 2.0 Wire Feed Unit	1129	285.3	322,143	155,109	167,034
2)	TM 350	542	649.93	352,264	251,703	100,561
3)	TM 225	407	415.78	169,226	102,207	67,018
4)	MT 2 TORCH	1271	76.04	96,643	41,481	55,162
5)	MTA 3 TORCH	685	91.85	62,915	27,960	34,954
6)	TM 600 (+ SMR 500)	140	875.05	122,507	92,069	30,438
7)	Lynxpak 200	92	652.70	60,049	38,213	21,836
8)	Lynx Universal WFU	127	403.8	51,283	38,229	13,054
9)	TM SPR	63	857.68	54,034	41,078	12,957
10)	Transcooler	169	232.97	39,373	28,574	10,799
	TOTAL: TOP TEN	4625	287.66	1,330,437	816,623	513,813
	TOTAL: Rectifiers (2, 3, 6, 7, 9)	1244	609.38	758,080	525,270	232,811

Table J.4

MIG Top Ten - Home sales on transfer value

		Qty	List Price	ASP by Gases	Trans. Price	Value	Cost	Contribn.
1)	TF 2.0 Wire Feed Unit	876	385.9	326.0	308.7	270,425	121,536	148,889
2)	TM 350	440	854.0	724.8	683.2	300,608	205,256	95,352
3)	TM 225	341	546.0	438.5	436.8	148,949	86,989	61,960
4)	MT 2 TORCH	778	106.3	94.7	85.0	66,136	24,103	42,033
5)	MTA 3 TORCH	498	126.8	110.7	101.4	50,513	20,215	30,298
6)	TM 600/(SMR 500)	115	1250/ 1002.8	1089.0 993.8	1000 802.2	101,948	75,841	26,107
7)	Lynxpak 200	67	840.0	786.4	672.0	45,024	27,506	17,518
8)	Lynx Universal	118	506.0	487.1	404.8	47,766	35,534	12,232
9)	MTW 5 TORCH	141	183.5	161.1	146.8	20,703	8,619	12,084
10)	3M Interconnections	384	91.6	81.8	73.3	28,152	16,719	11,432
	TOTAL - Home Top Ten	3758				1,080,224	622,318	457,905
NB								
11)	Transcooler	157	290.0	300.2	232.0	36,424	26,454	9,970
12)	TM SPR	26	1252.0	1106.2	1001.6	26,042	17,152	8,890
	TOTAL - Home value of overall top ten (Items 1 - 8, 11, 12)	3416				1,093,835	640,586	209,827
	Home value, rectifiers only (2, 3, 6, 7, 12)	989			Ave. TP 629.49	622,571	412,744	209,827

Table J.5

MIG Top Ten - Export sales

		Qty	ASP	Value	Cost	Contribn.
1)	TF 2.0 Wire Feed	253	204.4	51,718	33,573	18,145
2)	MT 2 TORCH	493	61.88	30,507	17,378	13,129
3)	TM 350	102	506.4	51,656	46,447	5,209
4)	TM 225	66	307.2	20,276	15,218	5,058
5)	MTA 3 TORCH	187	66.32	12,402	7,745	4,656
6)	TM 600/SMR 500	25	822.39	20,560	16,227	4,333
7)	Lynxpak 200	25	601.0	15,025	10,708	4,317
8)	TM SPR	37	756.54	27,992	23,926	4,067
9)	3M Interconnections	147	62.21	9,145	5,151	3,994
10)	MT15 TORCH	28	87.92	2,462	1,458	1,004
11)	Transcooler	12	245.75	2,949	2,120	829
12)	Lynx Universal	9	390.8	3,517	2,695	822
TOTAL:	Overall Top Ten (1-8, 11, 12)	1209		236,602	176,037	60,565
TOTAL:	Rectifiers (3, 4, 6, 7, 8)	255		135,509	112,526	22,984

Table J.6

TIG - Overall top ten on transfer value

	Qty	ASP	Value	Cost	Contribn.
1) TT AC/DC 375	384	1380.47	530,099	308,546	221,553
2) TT DC 250	76	2078.75	157,985	78,828	79,157
3) TA AC/DC 320	270	724.94	195,135	130,611	65,124
4) TT THF 450	295	290.81	85,788	40,462	45,326
5) TA DC 525	174	755.09	131,385	87,875	43,510
6) All TW 451 TORCHES	1143	61.6	70,381	29,161	41,220
7) TT THF 150L	273	275.33	75,164	45,263	29,901
8) Argon Flowmeter	2710	14.35	38,901	12,479	26,422
9) Water Cooler	326	242.02	78,899	55,883	23,016
10) TA DC 150	128	453.125	58,000	36,589	21,411
TOTAL: Top Ten	5779	246.12	1,422,337	825,697	596,640
TOTAL: Rectifiers (1,2,3,5,10)	1032	1039.93	1,073,204	642,449	430,755
NB: AC 350	28	1156.71	32,388	21,616	10,772
TCM 450	110	184.0	20,244	12,885	7,360
TSM 335	116	173.87	20,169	12,320	7,849
DC 825	38	992.76	37,725	26,588	11,137
Total including above			1,532,863	899,106	633,758

Table J.7

TIG Top Ten - Home sales on transfer value

		Qty	List Price	ASP by Gases	Transfer Price	Transfer Value	Cost	Contribn.
1.	TT AC/DC 375	282	1838.09	1596.57	1470.47	414,673	226,335	188,338
2.	TT DC 250	70	2670.70	2295.3	2136.56	149,559	72,594	76,965
3.	TA AC/DC 320 NB.Middle East 84	188	951.34 Ave.	714.90 Ave.	761.06 Ave.	143,080	90,270	52,810
4.	TA DC 525	154	966.76 Ave.	817.98 Ave.	773.41 Ave.	119,105	77,537	41,568
5.	All TW 451 Torches	825	81.14	78.97	64.91	53,552	21,300	32,252
6.	TT THF 450	162	393.96	339.68	315.17	51,057	22,295	28,762
7.	TT THF 150L	193	396.31	330.55	317.05	61,190	32,536	28,654
8.	Argon Flowmeter	2336	18.52	15.70	14.82	34,610	10,777	23,833
9.	Water Cooler	239	324.58	282.59	259.66	62,060	40,924	21,136
10.	TA DC 150	94	568.01	502.39	454.41	42,714	24,973	17,741
	TOTAL: Top Ten	4443			254.69 Ave.	1,131,600	619,541	512,059
	TOTAL: Rectifiers (1,2,3,4,10)	788			1102.96 Ave.	869,131	491,709	377,422
NB:	AC 350 (Rank No.15)	23	1509.98	1330.77	1207.98	27,784	17,968	9,816
	TCM 450(Rank No.22)	89	238.37	206.01	190.70	16,972	10,425	6,547
	TSM 335(Rank No.21)	91	227.56	200.42	182.05	16,566	9,652	6,914
	DC 825 (Rank No.16)	26	1328.88	1143.04	1063.1	27,641	18,165	9,476
	Total with above	4672				1,220,563	675,751	544,812

Table J.8

TIG Top Ten - Export Sales

		Qty	ASP	Value	Cost	Contribn.
1)	TT AC/DC 375	102	1131.63	115,426	82,211	33,215
2)	TT THF 450	133	261.14	34,731	18,167	16,564
3)	TA AC/DC 320	82	642.13	52,655	40,341	12,314
4)	All TW 451 Torches	318	52.92	16,829	7,861	8,968
5)	TA DC 150	34	449.59	15,286	11,616	3,670
6)	Argon Flowmeter	374	11.47	4,291	1,702	2,589
7)	TT DC 250	6	1404.33	8,426	6,234	2,192
8)	TA DC 525	20	614	12,280	10,338	1,942
9)	Water Cooler	87	193.55	16,839	14,959	1,880
10)	TT THF 150	80	174.67	13,974	12,727	1,247
	TOTAL - Top Ten	1236	235.22	290,737	206,156	84,581
	TOTAL - Rectifiers (1,3,5,7,8)	244	836.36	204,073	150,740	53,333
NB:	AC 350	5		4,604	3,648	956
	TCM 450	21		3,272	2,460	813
	TSM 335	25		3,603	2,668	935
		12		10,084	8,423	1,661
	Total with above	1299		312,300	223,355	88,946

Table J.9

MIG: Proportions of total business by sales, costs & contribution

MIG	Amount	MIG Home Sales	MIG Exp. Sales	MIG Tot. Sales	Total Home Sales	Total Exp. Sales	Total Sales
Rectifiers - Home							
Sales (TM 350, TM 225, SMR 500/ TM 600, Lynxpak 200, TM SPR)	622,571	36%		23%	11%		7%
Cost	412,744	35%		21%	11%		7%
Contribution	209,827	38%		27%	10%		7%
Rectifiers - Export							
Sales	135,509		20%	5%		5%	1%
Cost	112,525		21%	5%		6%	1%
Contribution	22,984		19%	3%		3%	-
Rectifiers - Global							
Sales	758,080			28%			8%
Cost	525,269			27%			9%
Contribution	232,811			30%			8%
Top ten items - Home							
Sales	1,093,835	64%		40%	19%		12%
Cost	640,586	55%		33%	17%		11%
Contribution	453,249	82%		59%	23%		15%

Table J.9 cont.

MIG: Proportions of total business by sales, costs & contribution

MIG	Amount	MIG Home Sales	MIG Exp. Sales	MIG Total Sales	Total Home Sales	Total Exp. Sales	Total Sales
Top ten items - Export							
Sales	236,602		36%	8%		9%	2%
Cost	176,037		34%	9%		9%	3%
Contribution	60,565		45%	7%		8%	2%
Top ten items - Global							
Sales	1,330,437			49%			15%
Cost	816,623			42%			14%
Contribution	513,814			67%			18%

Table J.10

TIG: Proportions of total business by sales, costs & contribution

TIG	Amount	TIG Home Sales	TIG Exp. Sales	TIG Total Sales	Total Home Sales	Total Exp. Sales	Total Sales
Rectifiers - Home (Top five)							
Sales	869,131	57.8%		40.0%	15.8%		10.1%
Costs	491,709	57.9%		37.8%	13.8%		8.5%
Contribution	377,422	57.6%		43.3%	19.4%		13.3%
Rectifiers - Export							
Sales	204,073		33.9%	9.4%		8.0%	2.4%
Costs	150,740		37.0%	11.6%		8.1%	2.6%
Contribution	53,333		27.3%	6.1%		7.8%	1.9%
Rectifiers - Global							
Sales	1,073,204			49.4%			12.5%
Costs	642,449			49.5%			11.1%
Contribution	430,755			49.4%			15.2%
Top ten products - Home							
Sales	1,131,600	75%		52%	20%		13%
Costs	619,541	72%		47%	17%		10%
Contribution	512,059	78%		58%	26%		18%

cont./

Table J.10 cont.

TIG: Proportions of total business by sales, costs & contribution

TIG	Amount	TIG Home Sales	TIG Exp. Sales	TIG Total Sales	Total Home Sales	Total Exp. Sales	Total Sales
Top ten products - Export							
Sales	290,737		48%	13%		11%	3%
Costs	206,156		50%	15%		11%	3%
Contribution	84,581		43%	9%		12%	2%
Top ten products - Global							
Sales	1,422,337			65%			16%
Costs	825,697			63%			14%
Contribution	596,640			68%			21%

Table J.11

TOP TEN - Rectifiers alone

	Qty.	ASP	Value	Cost	Contribn.
MIG					
1. TM 350	542	649.9	352,264	251,703	100,561
2. TM 225	407	415.8	169,226	102,207	67,018
3. Lynxpak 200	92	652.7	60,049	38,213	21,836
4. TM 600	56	995.2	55,734	38,534	17,200
5. SMR 500	84	794.9	66,773	53,535	13,238
6. TM SPR	63	847.7	54,034	41,078	12,957
	1244	609.4	758,080	525,270	232,810
TIG (Top five)					
1. TT AC/DC 375	384	1380.5	530,099	308,546	221,553
2. TT DC 250	76	2078.7	157,985	78,828	79,157
3. TA AC/DC 320	270	724.9	195,735	130,611	65,124
4. TA DC 525	174	755.0	131,385	87,875	43,510
5. TA DC 150	128	453.1	58,000	36,589	21,411
	1032	1039.93	1,073,204	642,449	430,755
TIG (Rectifiers from other major TIG items)					
DC 825	38	992.7	37,725	26,588	11,137

cont./

Table J.11 cont.

TOP TEN - Rectifiers alone

	Qty.	ASP	Value	Cost	Contribn.
AC 350	28	1156.7	37,725	26,588	11,137
Total- Top ten rectifiers	2276	804.61	1,831,284	1,167,719	663,565
Total - Top ten + 2 major TIG rectifiers	2342	811.87	1,901,397	1,215,923	685,474
NB. Autolynx	402	491.4	197,546	211,284	13,738

Table J.12

Proportions of business by contribution

Section of business	Contribn.	Proportion	Sub totals
MIG - Rectifiers	232,811	8%	
TF 2.0	167,034	6%	
Other top items	113,970	4%	MIG top ten 513,815 (18%)
All other items	250,185	9%	Total MIG 764,000 (27%)
TIG - Rectifiers (top five)	430,755	15%	
Other top ten items	165,885	6%	TIG top ten 596,640 (21%)
Other major items (AC350, DC825, TCM450, TSM335)	37,118	1%	TIG top 14 633,758 (22%)
All other items	238,242	9%	Total TIG 872,000 (31%)
PLASMA - All items	41,000	1%	
MANUAL - All items	294,000	10%	
PARTS & SERVICE	865,000	31%	
TOTAL	2,836,000	100%	

Summary table

	HOME	EXPORT	TOTAL
Rectifiers + Major TIG items	21%	3%	24%
Other top ten items	13%	3%	16%
Total	34%	6%	40%

e) The wire feed unit, TF 2.0, provides 6% of total contribution, on its own. (See J.12)

f) All items of MIG and TIG provide 58% of the business contribution. Assuming 80% of items are manufactured, then manufactured MIG and TIG items form 47% of the business, by contribution.

g) Costs at HWR (manufacturing site) form 59% of total costs (fixed and direct). (See Appendix

h) Since MIG + TIG top ten items form 68% of all MIG and TIG items, by contribution, and 80% of MIG and TIG items are assumed to be manufactured, then top ten MIG and TIG items form 85% of all manufactured items. Rectifiers form 51% of all manufactured items, by contribution.

J.2.4. Conclusions

The top ten items of MIG and TIG together produce 40% of the contribution of the business, and 85% of that from manufactured items.

Although rectifiers are considered to be the company's main product, they produce only 24% of total contribution from all manufactured items.

Manufactured items provide approximately 48% of contribution, but incur 59% of the total costs of the business.

J.3. Relationship between transfer price, volumes of sales, and contribution levels

Using the data from results of J.2 and assuming that a reduction in price of a product would result in an increase in sales, this investigation determines the amount of increased volume of sales required to maintain the contribution from that product. This was done for each of the top ten and extra two TIG rectifiers.

J.3.1. Method

Data from J.2 (Tables J.3 - J.8) were used to find the average transfer price and amount of contribution per unit for each item.

The transfer price was then discounted by 5%, 10%, 15% and 28% and average unit contribution which would result from these prices was calculated in each case. (See Table J.13) Average contribution per unit was then used to calculate the volume of sales and percentage increase required to maintain the total contribution from that product. (Amount shown in R.H. column of Table J.13.)

The same exercise was repeated for the other top ten items (J.14) and MIG packages (J.15).

J.3.2. Results (See Tables J.13, J.14 and J.15)

a) A 5% discount in transfer price of rectifiers would require sales volume increases of an average 19% for MIG and 14% for TIG rectifiers.

b) 10% discount in transfer price would require an average 48% increase in sales of MIG rectifiers, and 34% in TIG.

c) 15% discount in transfer price would require an average

95% increase in sales of MIG rectifiers, and 61% in TIG.
d) 20% discount in transfer price would require an average 18% increase in sales of MIG rectifiers and 10% in TIG.
(For (a) - (d) see Table J.13.)
e) Other MIG items: discounts in price of wire feed units and torches would require increase in sales of approx. 10% for 5% discount, approx. 22% for 10% discount, approx. 38% for 15% discount, and approx. 60% for 20% discount.

The Lynx universal would require increases in sales of 24%, 65%, 143% and 366% for discount of 5%, 10%, 15% and 20% respectively. (See Table J.14.)
f) Other TIG items: TIG torches would require increases in sales of 9% for 5% discount, 20% for 10% discount, 34% for 15% discount, 52% for 20% discount.

Increases in the argon flow meter would be just less than that required for torches.

Increases in sales of TT THF 450, TT THF 150L, TCM 450 and TSM 335 would be approximately 10-15% for 5% discount, 25-35% for 10% discount, 40-70% for 15% discount and 60-120% for 20% discount.

The water cooler would require the highest percentage increase in sales for reduction in price with 21% increase for 5% discount, 52% increase for 10% discount, 105% increase for 15% discount, 218% increase for 20% discount. (See Table J.14.)
g) Since MIG packages contain rectifiers, torches, wire feed units etc., volumes required to maintain contribution levels for reductions in price come midway between those for rectifiers and those for other items:-
approx. 15% increase required for 5% discount
approx. 35% increase required for 10% discount

approx. 70% increase required for 15% discount

approx. 110% increase required for 20% discount. (See Table J.15)

J.3.3. Conclusions

The increases in sales volumes required range from 10-20% for a 5% discount to 20-50% for a 10% discount, 35-100% for 15% discount, and up to 400% for a 20% discount. In general, increases required for rectifiers are higher than those required for equipment.

Appendix K. Validation of Market Survey data.

Index

Appendix K. Validation of Market Survey data.

The object was to compare data arising from the market survey data with that from some reliable source.

Since the most reliable source of data was Boc Arc Equipment itself, validation of the data consisted of comparing estimates of the size of Boc's share of the market with actual volumes of production. (Volumes of sales were not available for more than 2 or 3 years).

K.1 Data

Data estimating the size of the Boc share of the market was obtained from the market survey. Actual Boc Arc Equipment annual volumes of production were obtained from previous work. (Appendix C, 3.2.1.)

The following points must be made:

K.1.1 Market Survey data

a) The volume of sales for 1978 estimated from the number of sets one year old and the number of sets less than 1 year old as follows:

$$(\text{Number 1 year old and number under 1 year old}) \times \frac{12}{16}$$

This is on the assumption that the actual data covers a 16 month period, and is therefore reduced to that relevant to a 12 month period as shown.

b) Numbers for TIG include add-on units.

K.1.2 Boc Arc Equipment data and adjustments

a) The source of production volume data was the production programs. (See Appendix C.3.2.1), and data is for years ending in September.

b) These figures include volumes produced for export.

c) Volumes for other equipment manufacturers have been excluded.

d) MIG - volumes for Autolynx have been excluded as these are mainly sold to garages, part of the market not covered by the survey.

e) TIG - DC Manual has been excluded, hence volumes of production for TIG consist of TT DC 250, AC/DC 375, TAR 300 and TT AC 350, plus the appropriate predecessors.

Table K.1 - Numbers of sets from each source of data

	1972	1973	1974	1975	1976	1977	1978
<u>MIG</u>							
1) Market research data	476	990	799	1183	1153	1569	1307
2) BOC volumes produced (home and export)	805	1193	1602	1333	1325	1843	1248
3) Proportion 82% home sales	663	983	1320	1098	1092	1522	1025
Difference between (3) and (1)	+39%	-0.7%	+65%	-7.2%	-5.2%	-3.0%	-21.7%
<u>TIG</u>							
1) Market research data (includes add-ons)	437	551	576	1126	614	666	552
2) Market research data - proportion taken to exclude add-ons (73%)	319	402	420	822	448	486	403
3) Boc production volumes	491	386	636	587	561	599	563
4) Proportion for Home sales (78%)	383	301	496	458	437	467	439
Difference between (4) and (2)	-16.7%	+33.6%	-15.3%	+79.5%	+2.5%	+4.1%	-8.2%

K.2 Results

Comparison of the data from each source, when adjusted as shown, reveals the following:

a) Visual examination of data for MIG shows that volumes are approximately the same for 1973-78. (See Table K.1)

   Linear regression analysis produces a poor correlation between the two sets of figures, even for 1973-73, with C = 0.5, F = 1.7, not significant at 95% level.

   However there are good reasons why the annual variation in figures may not coincide.

   i) One set of figures applies to sales volumes and one to production volumes.

   ii) The market research data is compiled from estimates of the age of the set made by people answering the questionnaires. These estimates may not always be accurate.

b) Examination of data for TIG market size again shows that figures from the market survey and from Boc production volumes are on the same scale. (See Table K.1)

   Linear regression analysis of the correlation between the two sets of data again produces poor results, but the reasos for this are the same as for MIG. (see (a) above).

K.2 Conclusions

The results of this investigation validate the data from the market survey which estimates the sizes of annual sales of Boc, MIG and TIG sets.

Appendix L

Extracts from the UK Arc Equipment Market Survey 1979.

L.1 Introduction

1.1 Population sampled by the survey

1.2 Sampling methodology

1.3 Definition of market sectors and possibilities for analysis of data

1.4 Methods used in analysis

L.2 Executive summary (written by marketing manager)

L.3 Conclusions from market survey data on areas of potential volume growth for BOC AE.

3.1 Areas of potential volume growth for BOC AE

3.1.1 MIG

3.1.2 TIG

3.1.3 MMA

3.2 Possible future areas of volume growth; sectors currently with low volumes of sales but high growth rates.

3.2.1 MIG

3.2.2 TIG

3.2.3 MMA

3.3 Market sectors currently with high volumes but low growth rates

L.4 (Appendix B, Market Survey Report)
UK arc equipment market; projections of volumes for MIG and TIG sets, 1979-84.

4.1 Introduction

4.2 Summary of results

4.3 Market projections for MIG and TIG -methodology

4.4 MIG Market projections - Notes and assumptions

4.5 TIG Market projections - Notes and assumptions

L.5 (Appendix C, Market Survey Report)

UK Market Volume/value, MIG, TIG and MMA, Valuation of the market, 1978/79.

Tables

L.1 MIG - projections for MIG market 1979-84 (units)

L.2 Projections of BOC AE sales volumes on current market shares, 1979-84 (MIG).

L.3 TIG - projections for TIG market, 1979-84 (units)

L.4 Projections of BOC AE sales volumes on current market shares, 1979-84 (TIG).

L.5 MIG - derivation of growth rates used in projections for MIG welding market

L.6 MIG and TIG - Valuation of market 1978

L.7 MMA - Valuation of market 1978

Appendix L.1

UK Arc Equipment Survey - Introduction

1.1 The population sampled by the survey

Approximately 92,000 establishments were sampled by the survey, covering all industries and relevant services;

a) All engineering companies and those engaged in the fabrication of metal goods

b) Companies who manufacture non-metal goods; establishments with over 10 employees manufacturing chemicals; establishments with over 100 employees manufacturing food and drink; bricks, glass and cement; textiles, paper and plastics.

c) Builders, including general builders and contractors with over 14 employees; all heating and ventilation engineers and plant hirers and dealers.

d) Transport operators; haulage operators with more than 10 vehicles; bus companies (not private); railways (excluding railway workshops); and dock transport.

e) Skill centres and further education establishments, i.e. in Education.

f) Mines and quarries.

g) Universities and research; including all research establishments and electricity generating stations.

h) Farms with over 500 acres.

1.2 Sampling methodology

Sample size was weighted by size of the establishment, in order to avoid biassed results.

The range was between 1% sample of very small establishments (1-10 employees), 10% sample of very large establishments

(500+ employees).

The total sample size was 1450 establishments; these were all interviewed, the majority by telephone but some by personal interview to check accuracy and obtain further details.

The results were computer analysed and weighted by increase of sample size to give a representation of total market.

For further details of Market Research methodology, see Appendix A.

1.3 Definition of market sectors and possibilities for analysis of data

The data format enables two definitions of market sectors to be made:

a) by size and type of company, e.g. small fabricators, companies fabricating metal goods, with 11-99 employees;
b) by type of manufacture, e.g. iron and steel, vehicle manufacture etc.

It is also possible to find the cross break of these two definitions, e.g. the type of manufacture within a particular size and type of company.

The majority of analysis of market sectors has been done on the basis of sectors as defined in (a) above, i.e. by size and type of company.

The type of company is only sectored by size if the number of sets owned forms a large proportion of the welding set market.

The 13 sectors thus defined are as follows:

Fabricators - very small (1-10 employees)
small (11-99 employeed)
medium (100-499 employees)
large (500+ employees)

Engineers - small (1-99 employees)
medium/large (100+ employees)

Other sectors - Builders (all)
Non-metal manufacturers (all)
Education (all)
Universities and research (all)
Transport (all)
Mines and quarries
Farms

Analyses are possible on two types of data base;

i) The number of establishments welding; data is used to analyse the general characteristics of the market and of each sector, e.g. route to the market.

ii) The number of MIG, TIG or MMA sets owned, and the estimated age of the set.

This data is used to analyse specific characteristics of the separate MIG, TIG and MMA markets, also analysed by sectors.

For further details of the methodology used in analysis, see Appendix 2.

GKN Lincoln and Lincoln Electric - It was evident from the survey results that in many cases owners had given the brand of set as "Lincoln", and they or subsequent analysts had had to allocate the set to either GKN Lincoln or Lincoln Electric.

As the distinction between the two is blurred in the results, in the analyses results for the two have been combined under the brand name Lincoln.

The source documents referred to throughout are the computer tabulations of analyses of original data; copies may be consulted at

1.4 Methods used in analyses

a) Long term trends

Computer tabulations give results of the same analysis for both total population of sets and for sets less than 5 years old. Comparison of the two gives an indication of changes which have taken place over a long time period.

b) Short term trends

In all cases growth rates are estimated from linear regression through the 3 year MAT for 1972-77, and the average compound growth rate calculated from the end points of the best straight line.

The spread of data involved in this calculation is then 1971-78, i.e. from the age distribution of sets up to 8 years old, which is within the life expectancy of a MIG, TIG or MMA set.

L.2 Executive Summary (written by the Marketing Manager)

UK ARC EQUIPMENT MARKET SURVEY 1979

SUMMARY

OBJECTIVE

1) Estimate size of market in volume terms for MMA, MIG and TIG.

2) Segment the market by industrial sector and size of company.

3) Estimate growth in each process and market sector.

4) Identify major suppliers and their market shares.

5) Investigate customer attitudes to distribution routes and purchase criteria for choice of make of machine.

METHOD

A total of 1450 interviews were carried out in all relevant manufacturing industries, builders, plant hirers, installers and farms over 500 acres. The survey results were computer analysed to present a total market picture. Garages, small farms, very small builders and the consumer market were excluded.

RESULTS

	MIG	TIG	MMA
1. SIZE OF MARKET			
- No of Establishments welding	14000	10000	62000
- No of Welding Sets in use	51000	21000	195000
- Current volume sales per annum	7000	2250	12000
- Estimated value of sales per annum	£11m	£3m	£6m
2. MARKET GROWTH			
- Average compound growth rate (over last 6 years)	17% p.a.	10% p.a.	5% p.a.
- Current growth rate	13% p.a.	8% p.a.	4% p.a.
3. MARKET SHARES			
a) BOC			
- Total sets in use	22%	44%	28%
- Sets purchased in last 5 yrs	22%	35%	16%

N.B. Current BOC share of MIG market estimated to be 16% based on 78/79 sales.

	MIG	TIG	MMA
b) Major Competitors			
- Sets purchases in last 5 yrs.	Max arc 9% ESAB 8% AGA 8%	Interlas 25% ESAB 6% Maxarc 6%	Oxford 21% Philips 8% Pickhill 6%
- No. of competitors with 71% share	16	11	14
- % of market supplied by 'others'	7%	11%	14%

contd/...2

4) MARKET STRUCTURE BY INDUSTRIAL SECTOR

4.1 MIG

4.1.1 Growth Sectors

- Small companies in Fabrication and Engineering (1-99 employees)
- Medium companies in Fabrication (100-499 employees)

The growth is mainly due to process change to MIG which is still incomplete, particularly in very small fabricators (1-10 employees).

The small fabricators (26000 establishments) are a particularly important sector having purchased 48% of all MIG sets, AGA, Maxarc and GKN Lincoln being the major competitors.

4.1.2 Mature Sector

- Large Fabricators (500+ employees)

How growth in MIG ownership over last 6 years. BOC's share is 34% with Lincoln, Electric, Rockweld and Rowenarc the other major suppliers.

4.1.3 Others

There is some potential for MIG growth in educational and research establishments but the volumes are low.

4.2 TIG

4.2.1 Growth Sectors

- Small Fabricators and Engineers
- Medium Fabricators

Again, the growth is mainly due to process charge. Small Fabricators purchased 41% of all TIG sets sold in last 5 years, with the particular growth areas being Mechanical Machines and Steel Metalworks.

The BOC share is 45% in small fabricators and 25% in small engineers. Interlas is the major competitor in all sectors, with Maxarc and AGA growing.

4.2.2 Mature Sectors

- Large fabricators and Engineers.

Although these companies together form 23% of the total TIG market, low growth has been seen over the last 6 years.

The BOC share is 21%, with INterlas at an average of 40% across the sectors.

4.2.3 Others

The only other growth area for TIG is Builders which although small currently (4% of total market), experienced very high growth in the last 6 years. The BOC share is 13% with Hobart and Petbow being the major competitors.

contd/...3

4.3 MMA

4.3.1 Growth Sector

- Builders (small)
- Heating and Ventilation Engineers (large)
- Plant Dealers and Hirers.

The BOC share is 5%, with many competitors including Lincoln Electric, Hayters and Oxford.

4.3.2 Mature Sectors

The fabrication industry, although farming 50% of the total MMA market, is going through process to MIG and TIG. The market for new machines will continue to decline but the rate is not clear.

4.3.3 Others

There may be some growth potential in transport operators and non metal manufacturers but the volumes are relatively small.

5. ROUTES TO THE MARKET

Welding sets were purchased as follows:

	Manufacturer	Distributor
Small Fabricators	38%	62%
Large Fabricators	57%	43%
Other Manufacturers	38%	62%
Builders	41%	59%
Education & Others	26%	74%

6. PURCHASE CRITERIA

The key factors are

Price	(33%)	Performance	(23%)	Reliability	(15%)
Size	(15%)	After Sales Service	(10%)	Selling Method	(8%)

JKT/VH/19.12.1979

L.3 Conclusions from market research data on areas of potential volume growth for BOC AE

3.1 Areas of potential volume growth for BOC AE

3.1.1 MIG

There are four main areas, the first being by far the most important.

a) Small fabricators (11-99 employees)

BOC have only a small share of this large and growing market sector with increasing process change to MIG. The market requires reliable products in 200-399A range, buys through distributors and appears very price sensitive.

Thus, BOC should promote sales of TM 225 and 350 through distribution, preferably at more competitive prices, and ensuring availability of spares (for which they have a bad reputation).

b) Medium fabricators (100-499 employees)

The growth areas in this second largest market sector are in agricultural and other large plant, process plant and steelwork, tools, pumps and mechanical machines. Again there is a big process change to MIG.

This is allied with growing use of higher amp range MIG sets; 300-399A and 400-499A are now the favoured range of set, and there is growth in over 500A range.

Although BOC has 33% share of the whole sector, its strength is in the declining 200-299A range; it has only small shares of the higher amp range markets in the sector.

The market requires a reliable product which suits the work; it is not quite so price sensitive. It buys more from the manufacturer.

Thus, BOC should concentrate sales efforts on the higher amp ranges, ensuring reliability and counteracting its present reputation for non-availability of spare s.

BOC appear to have a gap in the product range 400-499A. Although the TM 350 can compete with competitive products in the lower end of the 400-499A range, it has insufficient fineness of voltage control and perceived power output for maximum operation on 1.2/1.6 hard and cored wires.

c) Very small fabricators (1-10 employees)

Very small companies in many fabrication areas have switched to MIG only in the last five years, giving this sector the highest growth rate.

Although BOC has highest share of this sector, it is declining.

Market requirements are those of small fabricators, but with even greater emphasis on price.

Again, BOC should promote sales of the TM 225 and 350, through distributors, at competitive prices. They appear to have strong competition in Rockweld, who combine reliability and simplicity with reasonable prices.

d) Small engineers (1-99 employees)

Although this is a small market sector, mainly in miscellaneous metal goods, it has very high growth rate, and BOC have only a small share.

Market requirements are for sets in the 400-499A, and 200-299A ranges, sold through distributors. Price is again important, but size, performance and after sales service are also considered.

In the 400-499A range, BOC have strong competition from GKN Lincoln who combine advantages in price, spares availability and reliability.

However, BOC could promote sales of TM 225 in this sector, but must compete on price.

Again, they are at a disadvantage, only having the TM 350 when competing in the 400-499A range.

3.1.2 TIG

Growth areas for TIG are the same as those for MIG, with the exception of medium fabricators. In all cases the process change from MMA which results in the large increase in MIG also involves a small increase in TIG.

a) Very small fabricators

Growth areas for TIG particularly in sheet metal work and mechanical machines. BOC have the highest share of this sector (48%).

General market requirements are the same as for MIG, 80% of TIG sales are in 300-399A range, remainder mostly 200-299A. Preference is for AC/DC and there is also a large market for add-ons.

Thus, BOC could improve their share if they concentrate on sales of AC/DC 375, selling through distributors and competing with Intelas and Maxarc on price. However they also have to compete with Intelas on quality and performance.

b) Small fabricators

Growth areas for TIG are agricultural construction and mechanical handling plant, mechanical machines and sheet metal work.

BOC are again fairly strong in this sector.

General market requirements are the same as for MIG; product range 200-399A with growth in 200-299A range.

Preference is split between AC/DC and AC only, with a quarter of requirements satisfied by add-ons.

Thus, BOC should promote sales of AC/DC 375 through distributors, although competition is strong. Many competitors concentrate solely on the 200-399A ranges. There seems to be a growing requirement for reasonably priced sets in the 200-299A range, which BOC cannot satisfy with their current product.

c) Small engineers

Growth in TIG in this sector, again almost all in miscellaneous metal goods, has occurred all in the last 5 years.

BOC are rather weak in the sector, with declining sales in the last 3 years.

Market requirement as for MIG. Favourite TIG range is the under 200A, which has high growth. 300-399A range is also growing in the sector.

There is a preference for DC only, with add-ons again satisfying a quarter of the market sector requirements.

The market for under 300A sets is mainly satisfied by the many small manufacturers. Potential for BOC to increase sales in 300-399A range is affected by the requirement for DC sets, which is satisfied by Intelas.

Thus, at present BOC does not appear to have the product for penetrating this sector. However, the new TT DC 180 should sell well in this sector, especially if sold through distributors, and if price and performance are right.

3.1.3 MMA

This sector has very high growth in MMA sets. Areas of high growth are in small builders and large heating and ventilation engineers.

BOC has only 5% of sets bought in last 5 years in this sector.

Market requirements are for price, size, range/power output and reliability. Product range required is equally split between under 200, 200-299, 300-399A, with preference for DC only sets increasing as the amp rating increases.

In the under 200A range, BOC is competing with Oxford and the hundreds of small manufacturers, on price, size and delivery.

In the 200-299A range, there is potential for competing with Hayters by selling through distributors on price and delivery. Does the BOC set satisfy requirements of size, mobility, range and power output?

300-399A range; BOC do have 12% of this market, but must compete with Lincoln Electric who sell through distributors and have good reputation for reliability and suitability of the product for the work.

NB. Customers report that one of BOC's disadvantages is that they rarely see the reps.

3.2 Possible future areas of volume growth; sectors currently with low volumes of sales but high growth rates

3.2.1. MIG

There are no major areas in this bracket for

MIG; although high growth is indicated in education, universities and research, the low numbers make any apparent trends very suspect.

3.2.2 TIG

There are two such areas for TIG:

a) Builders - small heating and ventilation engineers and plant dealers, medium size building companies, and large companies in building, heating and ventilation and plant dealers. For details see appendix.

b) Medium fabricators - growth in TIG indicated in vehicles, tools, pumps etc. (now 36% of this market) and ships; i.e. the areas which are declining in use of MIG. For details see appendix.

3.2.3 MMA

There are two such areas for MMA:

a) Transport - with growth areas in haulage operators, particularly small and medium sized, and bus companies. (Over 80% of sets are under 200A).

b) Non-metal manufacturers - growth areas in chemical industries, particularly in small companies.

3.3 Market sectors currently with high volumes but low growth rates

MIG

The main area for MIG with these characteristics is that of large fabricators. These play a decreasing part of the overall market, and are dominated by established companies. BOC currently have 34% market share in this sector.

TIG

Medium to large engineers, mainly in miscellaneous and metal goods, have preference for TIG sets. However growth in the market has been low for the past 6 years. BOC are second in the sector to Intelas, and have a reputation for being impersonal and with strike problems.

MMA

All fabricators fall into this area for sales of MMA sets - together they form 38% of MMA market but with very low growth rate in the last 6 years. BOC average share of this market is 18%.

L.4 (Appendix B) UK arc equipment market; projections of volumes for MIG and TIG sets, 1979-84

4.1 Introduction

a) The following volume projections for MIG and TIG sets, 1979-1984, are based on a segmentation of the market by the type of manufacture being done.

The resulting sectors correspond to SIC-coded industries, and so can be used in conjunction with published data and forecasts for those industries.

b) For the base year, 1977/78, the number of sets purchased by individual sectors has been estimated from the market survey data. (See main report.)

c) Projections from the base data for 1978/79 to 1983/84 have been made under the assumption that acquisition of MIG and TIG sets in each type of industry depends partly on the growth in that industry, and partly on the stat of process change to MIG and/or TIG in that industry.

d) Since acquisition of TIG sets in a particular sector did not necessarily correlate with industry growth in that sector, projections for volumes of TIG sets were made on a more tentative basis. As a result, less confidence should be placed on the projections for TIG market volumes.

e) Projected market share for BOC has been made on the assumption that the share held in each sector will remain constant.

(NB. Since each sector has a different projected growth rate for MIG, the resulting overall market share for BOC is not constant - see results.)

For further details of methodology, see Section 3.

4.2 Summary of results

a) Volume growth in MIG sets is expected to be fairly low until 1981, at around 5-6% p.a., whilst the economic recession is at its worst. With the predicted improvement in related industries in 1982-84, the volume growth rate in MIG gradually increases to approximately 10% p.a. by 1984.

b) The resulting size of the MIG market (number of sets) increases from approximately 7020 sets in 1978/79 to 10,600 sets in 1983/84.

c) Growth in MIG is expected to be highest in miscellaneous metal goods manufacture and mechanical engineering, particularly in agricultural equipment, process plant and mechanical machines.

This is due to some growth predicted in these industries, together with further anticipated process change to MIG.

d) BOC market share in MIG; the projections show a slight decline in market share for BOC, from 20% in 1977/78 to 19% in 1983/84. This is due to the relatively low shares of the high growth sectors held by BOC; generally their higher market shares are in sectors with predicted low growth in MIG.

e) Annual volume growth rates for TIG have been projected to increase from 5% p.a. in 1978/79 to 10% p.a. in 1983/84.

This rather tentative prediction is based mainly on a predicted increase in process change to TIG in industries where an envisaged reduction in steel consumption will result in a combination of reduced thickness of walls etc. with more use of high alloy steel, and hence greater use of TIG.

f) The highest projected growth in TIG is in sheet metalwork and subcontractors, on the assumption that the amount of work done by small fabricators and subcontractors will increase during economic recession.

g) BOC market share of the TIG market; the projections result in a slight increase in the BOC share of the TIG market, from 36% share in 1978/79 to 39%.

This is due to the high BOC share held in the sheetmetal, subcontractors sectors, where high growth rates are anticipated for TIG sets.

Table L.1 UK MARKET SEGMENTATION & VOLUMES

A. MIG– Projections for MIG Market (units). (90% of market)

		Base 1978	1979	1980	1981	1982	1983	1984
1)	Vehicles	888	806	835	908	962	937	958
2)	Ships	142	132	126	120	116	112	110
3)	Iron, Steel etc	89	85	82	82	83	85	87
4)	Mechanical Eng.							
	a) Agricultural Equipt.	478	500	522	546	571	597	624
	b) Construction & Mech. Handling Equipt.	688	681	667	680	693	714	743
	c) Process Plant	524	547	560	585	624	679	747
	d) Tools etc.	222	233	245	260	276	296	317
	e) Sub contractors	631	685	763	882	991	1093	1193
	f) Mechanical m/s	579	643	708	772	834	893	947
	Mechanical Eng.– Total	3122	3289	3465	3725	3989	4272	4571
5)	Miscellaneous Metal Goods							
	Sheetmetal work	975	1119	1225	1366	1582	1849	2163
	Misc. Metal Plant	639	734	804	896	1038	1213	1419
	Instruments, etc.	17	19	22	25	28	33	40
	Misc metal goods–Total	1631	1872	2051	2287	2648	3095	3622
6)	Electrical Engineering	120	132	145	160	176	193	212
	Total for 90%	5992	6316	6704	7282	7974	8694	9560
	Annual Growth Rates		+5.4	+6.1	+8.6	+9.5	+9.0	+10.0

GRAND TOTAL (TOTAL x 10/9)

	1978	1979	1980	1981	1982	1983	1984
GRAND TOTAL	6658	7018	7449	8091	8860	9660	10622

Table 1.2 Projections of BOC AE sales volumes- MIG

BOC SALES VOLUME (ASSUMING 20% MARKET SHARE) ON CURRENT MARKET SHARES (ON 90% MARKET)

		BOC Share	Base 1978	1979	1980	1981	1982	1983	1984
1)	Vehicles	(19%)	169	153	159	172	183	178	182
2)	Ships	(40%)	57	53	50	48	46	45	44
3)	Iron, Steel etc	(8%)	7	7	7	7	7	7	7
4)	a) Agric & const.	(21%)	245	248	250	257	265	275	287
	b) Process Plant	(38%)	199	208	213	222	237	258	284
	c) Tools, pumps	(52%)	115	121	127	135	143	154	165
	*d) Subcontractors	(14%)	88	96	107	123	139	153	167
	*e) Mechanical m/s	(14%)	81	90	99	108	117	125	133
5)	*a) Sheetmetal work	(14%)	136	157	171	191	221	259	303
	*b) Misc metal plnt	(16%)	102	117	129	143	166	194	227
	*c) Instruments, cables	(26%)	4	5	6	6	7	9	10
6)	Electrical Eng.	(5%)	6	7	7	8	9	10	11
	BOC- 90% Market		1209	1262	1325	1420	1540	1667	1820
	Annual Growth Rate			4.4%	5%	7.2%	8.4%	8.2%	9.2%
	Market Share		20%	20%	19.8%	19.5%	19.3%	19.2%	19.0%

* - Sectors with high growth rates in MIG.

Table L.3

B. TIG - PROJECTIONS FOR TIG MARKET (UNITS)

		Base 1978	1979	1980	1981	1982	1983	1984
1)	Vehicles	65	59	61	66	70	68	70
2)	Ships	79	83	87	91	96	101	106
3)	Iron & Steel	77	73	69	66	63	60	57
4)	Agricultural, const., & mech. handling plant	42	44	47	50	53	56	60
5)	Process Plant	202	192	179	170	165	163	163
6)	Tools, pumps etc.	66	71	76	81	87	93	100
7)	Mechanical m/s	212	233	257	282	310	341	376
8)	Sheetmetal & sub-contractors	580	653	742	847	975	1141	1339
9)	Misc. metal goods							
	- Aerospace	250	245	240	235	231	226	221
	- Other	258	271	284	299	314	329	346
10)	Electrical Engineering	16	15	14	13	12	11	10
	Total fabricators & eng. growth rates	1847	1939	2056	2200	2376	2589	2848
			+5%	+6%	+7%	+8%	+9%	+10%
	Education	133	140	148	158	171	186	204
	Others	168	176	187	200	216	236	260
	Total	2148	2255	2391	2558	2763	3011	3312
			+5%	+6%	+7%	+8%	+9%	+10%

Table L.4

Projections of BOC AE sales volumes on current market shares, TIG

	BOC Share	BOC sales volumes: Base 1978	1979	1980	1981	1982	1983	1984
1) Vehicles	17%	11	10	10	11	12	12	12
2) Ships	44%	35	36	38	40	42	44	47
3) Iron & Steel	16%	12	12	11	11	10	10	9
4) Agricultural constr., & mech. handling & plant	0	-	-	-	-	-	-	-
5) Process plant	37%	75	71	66	63	61	60	60
6) Tools, pumps etc.	73%	48	52	55	59	63	68	73
7) Mechanical machines	15%	32	35	39	42	46	51	56
8) Sheetmetals & subcontractors	55%	319	359	408	466	536	628	736
9) Misc. metal goods	27%	137	139	141	144	147	150	153
10) Electrical eng.	51%	8	8	7	7	6	6	5
Total fabricators & engineering.		677	722	775	843	923	1029	1151
Growth rates p.a.			6.6%	7.3%	8.8%	9.5%	11.5%	11.9%
Education	34%	45	48	50	54	58	63	69
Others	23%	39	40	43	46	50	54	60
Total		761	810	868	943	1031	1146	1280
Growth rate			6.4%	7.2%	8.6%	9.3%	11.1%	11.7%
BOC market share		35%	36%	36%	37%	37%	38%	39%

4.3 Market projections for MIG and TIG - methodology

4.3.1 Projections are made only for the metal fabrication and engineering sectors, since this represents 90% of the MIG market and 86% of the TIG market.

The remainder of purchases of both MIG and TIG sets are spread over a wide variety of sectors, generally with spasmodic demand patterns. (See main report for details.) Thus, projection of volumes of sales for these sectors are difficult.

For this reason, volume totals for both markets have been estimated from projections for the fabrication and engineering sectors, scaled up by the appropriate factor (i.e. 10/ for MIG, 100/86 = 1.16 for TIG).

4.3.2 Data for the base year (1977/78) is calculated from the market survey data as follows.

The number of sets purchased each year is estimated from the age distribution data for all sets:

a) Errors in estimation of the age of the set are smoothed by taking a 3 year MAT.

b) The number of sets purchased in the base year is estimated from the best straight line taken through the smoothed data for the last 6 years.

4.3.3 Future process change in each sector has been estimated from two sources:

a) The historical trend represented by the comparison of the growth in the industry sector with the growth in arc welding equipment in that sector over the last six years.

b) The projected change in percentage of welding metal deposited for that industry, indicating which process will be used. Source: Trends in Arc Welding by Kenneth Wilson, August 1978.

4.3.4 Forecasts of industry growth are available for certain sectors only, and frequently are not available for individual industries. Forecasts for these industries have been made on the basis of any information available; mainly from NEDO working parties for each industry.

Sources of industry forecasts include:

UK Quarterly Economic Assessment by Mike Speldman,
(BOC economist) August 1979

Henley Forecasting Centre

Cambridge Econometrics (Press release, October 1979)

NEDO publications - the most recent forecasts or
working party reports, where available.

4.3.5 Individual forecasts - MIG: It was found that historical growth in an industrial sector coincided with growth in acquisition of sets by that sector. The additional growth in MIG due to process change was estimated, and continuation of this process change was considered and estimated for each type of industry.

The projected volume of sales of MIG sets in that sector was then estimated from a combination of the growth forecast in that industry with the estimated growth in MIG due to process change.

Notes on individual industry forecasts and the assumed growth rates are given in section 4: (MIG - Notes and assumptions.)

4.3.6 Individual forecasts - TIG: In general, sales of TIG sets do not correspond with trends in the respective industries. Thus, the forecasts for sales of TIG have been compiled in a different way from MIG:

a) Total market volumes have been projected using growth rates increasing from 5% p.a. (1979) to 10% p.a. (1984).

b) In most sectors an overall growth rate for TIG has been estimated from consideration of past trends both in the industry and in TIG sales in the sector, industry forecasts, and possible future process change to TIG in the industry.

c) Projections for the remaining sector, sheetmetalwork and subcontractors, have been calculated on the basis of fitting in with overall totals.

The resulting high growth rates in these sectors, increasing from 13% 1978/79 to 17% in 1983/84 is thought to be justified by the probably increase in work done by small fabricators and subcontractors in times of economic recession. (For notes on assumptions and predicted growth rates, see section 4 - TIG - Notes and Assumptions.)

4.3.6 Reliability of forecasts - Volumes of MIG sets bought by each industry and the growth of that industry seem to be strongly related. Thus, forecasts of sales of MIG, although dependent on the accuracy of industry forecasts, at least have some basis for prediction.

However, far less confidence is placed in the forecasts for volumes of TIG sets, as these have to be made more or less independently of industry forecasts.

4.4 MIG Market projections-Notes and assumptions

1) Vehicles

Process change; considered complete, no further process change projected.

Industry growth; based on individual annual growth in car production from Henley forecasting Centre.

2) Ships

Process change; further slight process change to MIG estimated at 3% p.a.

Industry growth; the severe recession in merchant shipbuilding (forecast - 20% 1979 and - 10% 1980, see UK Quarterly Economic Assessment by Mike Speldman), is thought to be mitigated by growth in Naval shipping and small boats.

Hence accept forecasts from Cambridge Econometrics.

3) Iron & Steel

Process change; only slight continuing process change for MIG of 2% p.a.

Industry growth; from Cambridge Econometrics.

contd....

4.4) Mechanical Engineering and Constituent Industries

Figures for constituent industries were fitted inside the total for mechanical engineering.

Mechanical Engineering

Process change; calculated from weighted average of;

	Predicted Process Change	% of Total
Agricultural etc M/s	2% p.a.	47%
Industrial process plant	19% p.a.	21%
Tools	3%	9%
Mechanical machines	10%	23%

Weighted average growth due to process change; 7.5% p.a. As process change will not continue indefinately, this is reduced to 5% p.a. from 1982 onwards.

Industry growth; Henley forecasting centre and Mike Speldman's UK Quarterly Economic Assessment agree on average, Cambridge Econometrics give more severe recession 1979 -1980.

Source used; Mike Speldman's UK Quarterly Economic Assess.

Individual constituents of mechanical engineering;

a) Agricultural Equipment (41% of agric + construct. + mech. handling)

Process change; 2% p.a.

Industry growth; Investment in UK agricultural industry forecast at average 2.5% p.a. (NEDO working party). No slump envisaged for world market - growth is developing countries in 3rd world.

Growth rate projected at 2.5% p.a.

b) Construction Equipment (24% of agricultural etc)

Process change; 2% p.a.

Industry growth; Reduction of expenditure expected in public sector of UK construction industry, with further and larger cuts in civil engineering programs likely. Exports likely to be affected by the sterling situation, and by reduction of civil engineering projects in the Middle East, also by drop in investment in North Sea oil.

Growth rates - follow those forecast for public sector of construction industry.

c) Mechanical Handling Equipment (25% of agricultural etc)

As construction equipment.

contd.....

4.4) <u>Mechanical Engineering and Constituent Industries</u> (continued)

d) <u>Process Plant</u>

Process change; initial estimate 15% p.a. later reduced to 10% p.a.

Industry growth; Severe slump forecast for 1980, 1981, and 1982, trend in 1983 still downwards although not so severe.

Investment in chemicals, oil and gas production, and petroleum refining and distribution all decline drastically.

The only growth in investment is in electricity generating plant.

Growth rates; - 7% in 1980 reducing gradually to 0% in 1984.

e) <u>Tools, Pumps etc</u>

Process change; 3% p.a.

Industry growth; according to NEDO working party report has been consistently above industry norm.

Growth rates; 2% p.a. 1979 and 1980 rising gradually to 4% p.a. by 1984.

f) <u>Mechanical Machines</u>

Process change; 10% p.a., reducing to 5% p.a. by 1984.

Industry growth; considered by constituent industries.

Mining machines	(15% total)	+ 5% p.a. growth
Textile machines	(14% total)	- 5% p.a. growth
Printing machines	(6% total)	Flat demand forecast
Fridges etc.	(19% total)	+ 5% p.a. growth
Food Processing M/c	(12% total)	+ 3% p.a. growth
Remainder	(32% total)	- 1% p.a. growth

Estimates based on projections by Cambridge Econometrics of what will happen in the relevant consumer industry.

<u>Overall impression;</u> <u>1% p.a. growth</u>

g) <u>Sub-contractors</u>

Process change and industry growth in this sector is estimated to be higher than the industry average. Growth in sub-contractor business is thought to coincide with depression in main manufacturing businesses.

4.5) <u>Miscellaneous Metal Goods</u>

Process change; 15% p.a. initially, reducing gradually to 10% p.a. by 1984.

Industry growth; Recession predicted for 1980, followed by recovery from 1981 onwards.

Growth rates; Cambridge Econometric forecasts + 4% (thought to be over depressed).

4.6) <u>Electrical Engineering</u>

No information available on process change or industry growth;

Growth rates projected at straight 10% p.a.

Table L.5

MIG - DERIVATION OF GROWTH RATES USED IN PROJECTIONS FOR MIG WELDING MARKET (ALL PERCENTAGE CHANGE)

		Base 1978	1979	1980	1981	1982	1983	1984
1)	Vehicles							
	Process change-nil							
	Industry growth		-9.2	+3.6	+8.7	+6.0	-2.6	+2.3
2)	Ships							
	Process change		+3.0	+3.0	+3.0	+3.0	+3.0	+3.0
	Industry growth (Cambridge)		-9.8	-7.3	-7.2	-6.5	-6.3	-4.8
	Combined growth rate		-7.1	-4.5	-4.4	-3.6	-3.4	-1.9
3)	Iron, Steel etc.							
	Process change		+2.0	+2.0	+2.0	+2.0	+2.0	+2.0
	Industry growth (Cambridge)		-6.6	-5.8	-1.9	-1.1	-0.1	+0.3
	Combined growth rate		(-4.7)	(-3.9)	(+0.6)	(+0.9)	(+1.8)	(+2.3)
4)	Mechanical Engineering							
	Total Process change		+7.5	+7.5	+7.5	+5.0	+5.0	+5.0
	Industry growth (Est) (Mike Speldman)		-2.0	-2.0	0	+2.0	+2.0	+2.0
			+5.4	+5.4	+7.5	+7.1	+7.1	+7.1
5)	Agricultural Equpt.							
	Process change		+2.0	+2.0	+2.0	+2.0	+2.0	+2.0
	Industry growth (est)		+2.5	+2.5	+2.5	+2.5	+2.5	+2.5
	Combined growth rate		4.55% p.a. THROUGHOUT					
6)	Construction & Mech. Handling Equipt.							
	Process Change		+2.0	+2.0	+2.0	+2.0	+2.0	+2.0
	Ind. Growth (NEDD Book)		-3.0	-4.0	0	0	+1.0	+2.0
			-1.1	-2.1	+2.0	+2.0	+3.0	+4.0

Table L.5 -continued

MIG -DERIVATION OF GROWTH RATES USED IN PROJECTIONS - CONT.

		Base 1978	1979	1980	1981	1982	1983	1984
7)	Process Plant							
	Process change		+10.0	+10.0	+10.0	+10.0	+10.0	+10.0
	Industry growth		-5.0	-7.0	-5.0	-3.0	-1.0	0
	Combined growth		+4.5	+2.3	+4.5	+6.7	+8.9	+10.0
8)	Tools etc.							
	Process change		+3.0	+3.0	+3.0	+3.0	+3.0	+3.0
	Industry growth		+2.0	+2.0	+3.0	+3.0	+4.0	+4.0
	Combined growth		+5.1	+5.1	+6.1	+6.1	+7.1	+7.1
9)	Sub-contractors							
	By deduction		+8.5%	+11.4%	15.6%	12.3%	10.3%	9.1%
10)	Mechanical m/s							
	Process change		+10.0	+9.0	+8.0	+7.0	+6.0	+5.0
	Industry growth		+1.0	+1.0	+1.0	+1.0	+1.0	+1.0
			+11.1	+10.1	+9.1	+8.1	+7.1	+6.0
11)	Miscellaneous Metal Goods							
	Process change		+15.0	+14.0	+13.0	+12.0	+11.0	+10.0
	Industry Growth (Cambridge + 4%)		-0.2	-3.9	-1.3	+3.4	+5.3	+6.4
			+14.8	+9.5	+11.5	+15.8	+16.9	+17.0

12) Electrical Engineering — Straight 10% p.a. growth

13) Sheetmetal work and miscellaneous metal plant - as miscellaneous metal goods.

5. TIG Market Projections - Notes and assumptions

5.1) Vehicles

Again no process change envisaged, trends in TIG sales follow trends in car production (Henley forecast).

5.2) Ships

As there is growth in naval shipping and small yachts; naval shipping uses high tensile and high alloy steels, small yachts use a lot of stainless steel, we assume there will be growth in TIG sales in this sector.

Projected growth rate; 5% p.a.

5.3) Iron and Steel

From historical analysis, growth in TIG in this sector is 2% below industry growth.

Cambridge Econometrics forecast average 3% decline in the iron and steel industry, hence;

Projected growth rate – 5% p.a.

5.4) Agricultural and Construction, Mechanical Handling Plant

Although industry growth forecasts are pessimistic, some parts of the sector, e.g., mechanical handling plant, are liable to be subject to the trend towards using a higher proportion of high alloy steel in their construction in order to give more strength with no increase in weight.

Thus there is liable to be further process change to TIG in this sector.

Projected growth rate; 5% p.a.

5.5) Process Plant

Again in this industry there will be a tendency towards reducing steel consumption by reducing thickness of walls etc., and by using high alloy steel.

However, in the main sales of TIG will follow the slump in the industry.

Projected growth rates;

1979	1980	1981	1982	1983	1984
– 5%	– 7%	– 5%	– 3%	– 1%	0

5.6) Tools, Pumps etc.,

TIG sales in this sector have been erratic in the past, although showing overall high growth rate. Some growth is forecast.

Projected growth rate; 5% p.a.

5.7) Mechanical Machines

The industries using a lot of TIG welding; mining machinery, fridge and heating equipment, food processing machinery, are the ones where forecasts of growth are good. Since there is also still potential in these industries for process change to TIG, high growth for TIG is envisaged in this sector.

Projected growth rate; 10% p.a.

5.8) Miscellaneous Metal; sub-contractors and sheetmetal work.

5.9) Miscellaneous Metal - Aerospace

Sales of TIG are expected to follow the decline in this industry.

Projected growth rates; - 2% p.a.

5.10) Miscellaneous Metal - Other

In the absence of any other information, historical growth in TIG is expected to continue.

Projected growth rate; 5% p.a.

5.11) Electrical Engineering

Again, in the absence of any other information, the historical trend has been projected into the future i.e., a decline.

Projected grwoth rate; decline average - 8% p.a.

Appendix L.5 (Appendix C of Market Survey Report)

UK Market Volume/value

MIG, TIG and MMA, Valuation of Market - 1978/79

	No. of sets	Value £
MIG	7040	8,786,600
TIG	2248	3,348,640
MMA	11,635	5,787,050
TOTAL	20,923	17,922,290

Table L.6

MIG & TIG - VALUATION OF MARKET

1978

			No.	Prop^n	ASP £	Value £K	Prop^n
MIG							
1)	Under 150A		97	1%	550	53.35	1%
2)	150 - 199A		341	5%	750	255.75	3%
3)	200 - 300A		2,532	36%	1,000	2,532.00	29%
4)	300 - 400A		2,510	36%	1,250	3,137.50	35%
5)	400A +		1,560	22%	1,800	2,808.00	32%
			7,040	100%		8,786.60	100%
TIG							
1)	Under 200A	- sets	261	12%	1,100	287.10	8%
		- add ons	313	14%	520	162.76	5%
2)	200 - 299A (24% of 200 - 399A)	- sets	213	9%	1,705	363.16	11%
		- add ons	96	4%	660	63.36	2%
3)	300A +	- sets	941	42%	2,420	2,277.22	68%
		- add ons	424	19%	460	~~178.08~~ 195.04	6%
			2,248	100%		3348.64 3,331.68	100%
	Sub Total - Add ons		833	37%		~~382.79~~ 421.16	13%

ASP is at current list price.

Table L.7

MMA - VALUATION OF MARKET

	No.	Prop^n	ASP £	Value £K	Prop^n
1) AC MANUAL					
Up to 150 (38.5% of under 200A)	1,423	17%	70	99.61	4%
150 - 200 (61.5% of under 200A)	2,272	28%	120	272.64	11%
220 - 300 (43% of 200-399A)	1,535	19%	370	567.95	23%
300 - 400 (57% of 200-399A)	2,021	25%	500	1,010.50	40%
400 - 650+	866	11%	650	562.90	22%
TOTAL	8,177	100%	310 Ave.	2,513.60	100%
2) DC MANUAL					
Up to 200A	522	17%	650	339.30	11%
200 - 300A (43% of 200 - 399A)	679	22%	750	509.55	27%
300 - 399A (57% of 200 - 399A)	901	30%	1,000	901.00	31%
400 - 599A	534	18%	1,100	587.40	20%
600+	382	13%	1,600	611.20	21%
	3,018	100%	977 Ave.	2,948.45	100%
TOTAL MANUAL	11,135			5,462.05	
+ DON'T KNOWS	500		Say 650	325.00	
	11,635			5,787.05	