AN INVESTIGATION OF NATURE OF THE WORKING RELATIONSHIP BETWEEN PRODUCT DESIGN AND PRODUCTION FUNCTIONS IN MANUFACTURING COMPANIES

A Thesis submitted for the Degree
of Doctor of Philosophy
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VOLUME II

APPENDICES

Volume 2

Appendices

Introductory Notes

These appendices contain primarily the material collected by the researcher in the form of twenty case studies. It also contains the questionnaire, and the broad guidelines used to conduct field research in the participating firms.

The case studies are presented in a consistent manner. Each case starts with introduction, followed by Product Specification and Design and Development process and ends with general observations which were relevant to this research project.

It is adviseable for the reader of this thesis to read the case material prior to reading Discussion and Analysis Chapter (Volume 1).

List of Figures in the Appendices

APPENDIX 1

PRODUCTION/PRODUCT DESIGN QUESTIONNAIRE

1 In your factory or plant, approximately:

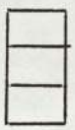
- How many people work in Production?
- How many people work in Product Design?
- How many types of products do you manufacture?

THINKING ABOUT NEW PRODUCTS IN YOUR COMPANY

Please tick
as approprpiate

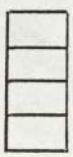
2 What is your most common source of new product designs?

- Design department within your company
- Customers instructions
- Other source (please indicate)



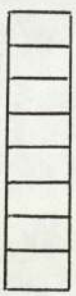
3 Generally, to what extent is your Production department involved in the design process?

- Not at all
- During handover from Design to Production
- Throughout the design period
- In some other way (please indicate)



4 Please indicate, from your experience, which of the following features of your Production department are considered during the design process.

- Workforce skills
- Technical performance of equipment
- Plant capacity
- Existing products
- Production control
- Stock control
- Others (please specify)
- No consideration given to any features.



5 On average, how frequently is a new product design introduced in your Production department?
(eg '3 times per month')

6 Is there a policy of standardising components used in new designs?

YES/NO

If your reply is NO, is this because:

- all products are 'special'
- Standardisation is not appropriate
- Some other reason (please indicate)

If the reply is YES, would you classify the approach as:

- "Formal standardisation" (ie preferred designs specified and listed, variation the exception rather than the rule)

- "Informal standardisation" (ie designer attempts to achieve standardisation, but on the basis of judgement rather than guidelines)

7 In your opinion, is the working relationship between Design and Production in your company satisfactory?

YES/NO

If YES, briefly indicate features which you believe make the relationship satisfactory.

If NO, in what respects would you like to see change occur?

THINKING ABOUT EXISTING PRODUCTS

8 On average, how frequently does a change occur in the design of eixsting products which necessitates attention to your production system? (eg 'once per product per year')

9 Is Production usually consulted before the change occurs? If YES, what form does the consultation take?

YES/NO

If NO, how are changes communicated to Production? (eg reissued drawings, internal memo, etc).

THANK YOU for answering these questions. If you would like to make any additional comments, please use the space below.

APPENDIX 2

BROAD GUIDELINES FOR FIELD RESEARCH

The following areas will be investigated during the field research:

1 Product enquiry stage: (if applicable to the relvant company)

- Number and type of staff involved as well as method adopted in arriving at an estimated price?
- Degree and frequency of involvement of various staff. For example, is it through meetings, groups discussions, memos, personal contact etc?
- Does a formal system of communication exist?

2 Product spectification - who is involved and the extent of involvement in drawing up of product specification.

- for example are design, production, sales, accounts etc involved.
- the format of the specification
  ie written or verbal

3 Design/Development stage

- Designers initial impression? (monitor this by interviews and observations.
- Degree and frequency of involvement of other staff such as Production Management or others?
- Does a formal system of communication with other staff exist?

  For example, is the progress of the design monitored by regular meetings, discussions or other ways?
- To what extent is the Designer aware of production methods available within the company?
- During the design of a product does the Designer consider features such as work force skill, technical capability of equiment plant capacity, material availability etc.

4 Handover of drawings from Design to Production stage:

- How and to whom are the drawings and list of materials issued?
- Is all the information required for manufacture of a product conveyed to the recipient or are there any comebacks from Production to Design?
- Initial impression of Production or recipient of the drawings? (monitor this by interview and observations).

5 Modification procedure:

- Are there any changes or clarification on a design requested by Production after all the drawings have been issued?

- Degree and frequency of changes requested or required?

- Are these changes simply personal disagrement or are they genuine?

- Does a formal modification procedure exist?

Appendix 3

HA Limited

This organisation has been established for around 20 years, it was started in Scotland but in 1976 the head office and its manufacturing operations were moved to the Midlands. Currently it employs 350 people and turnover is in the region of £12 million a year. HA Limited has a complex, yet effective sales, distribution and hire network which it operates from 15 regional areas. Each region has its own Sales Director, managers and representatives. In fact the majority of its total workforce is engaged in this sector of the industry.

At its main headquarters the firm is divided into four divisions, namely, manufacturing, refrigeration, heating and export. These are well supported by the general administration side of the company. All except its refrigeration division are based at its Midlands site, which is based in the South of England.

The company's day-to-day running is left to the Directors and the divisional managers but the overall responsibility and ownership is still maintained by the Chairman who is the original founder.

HA Limited, as well as supplying a range of heating and refrigeration products in the UK it also exports about 10% of its total production output. The company has been successful in exporting to West Germany, Hungary, Japan, Iceland, Iran, USA, Italy and Mozambique. The Export Manager takes care of this area.

The company's design and development team is under the leadership of the Technical Manager. This department is split into four district areas:-

- development department - consists of a development manager and a development engineer.
- drawing office - consists of a manager and two draughtsmen.
- servicing area - includes a manager and two storekeepers.

The manufacturing operations of the company are run by the Works Manager who is supported by Foremen and about 40 Operators.

The company's premises are quite old and dilapidated and has a fairly small workshop area, consisting of welding, assembly, painting and development facilities. The majority of its manufacturing work is sub-contracted out; the management prefers this arrangement due to low capital investment in plant and equipment. Strictly speaking the company indulges in design, development and assembly operations only.

The design process of a new product is usually initiated through one or more of the following sources:

(i) Each regional area usually prepare regular reports, highlighting main trends and the future requirements of the customers and these are widely circulated throughout the organisation, including the Technical department.

(ii) The Technical department sometimes prepare questionnaires in order to gauge opinion/ comments etc from each region, about a specific product which the technical function is intending to develop in the future.

(iii) The Technical Manager, in January/February of each year, visits all regional areas and discusses possible future opportunities with the directors, managers and sales representatives.

In addition to this extra information is collected from trade associations and institutions and all this is used to initiate product design process.

The Technical Manager collates all the relevant details from the above mentioned sources and compiles them into a report and this is widely circulated throughout the company. The report usually explores two possibilities:

(i) a decision to modify an existing product
(ii) a decision to design a completely new product.

Once this decision has been taken, a product specification is devised in conjunction with the regional areas, the main board, the Service department and the technical section. This is followed by the preparation of a programme chart highlighting the work to be carried out broken down into weekly targets.

The company, since in the business of supplying heating appliances, usually launches their new products in August/ September in readiness for the winter period.

Once the details on the Production Specification are finalised, the design and development work commences by one of the following ways:

(a) design according to the specification and then pass on the drawings to the development workshop so that a prototype model can be constructed.

(b) develop the product from the guidelines laid out in the design brief and then prepare detailed drawings.

(c) a combination of (a) and (b).

The weekly programme chart for each product is usually quite flexible and the progress of each project is monitored and assessed at regular monthly meetings. As a result of these meetings the priority ratings of the projects may change.

The project followed in this particular case study is a direct fired gas heater (DFGH). The series of events which took place are described as follows:

Product Specification

The project started when an analysis of the regional reports indicated a gap in the market for a direct fired gas heater. The Technical Manager broadly discussed this with the Chairman, who suggested that a heater of this type was already available in Spain. In fact, HA Limited bought the legal rights to this heater from the Spanish company with a view of modifying it and subsequently manufacturing it under their own brand name.

The Technical Manager during his annual regional visits discussed the possibility of this new model (DFGH) with the regional personnel and the response was quite favourable. As a result the project was started.

The specification was very broad and was based around the existing Spanish design. The body of this cabinet heater consists mainly of an outer shell constructed from sheet metal and the firm's own calor gas bottle is incorporated inside with a heating unit. This heater is intended to achieve a maximum realistic output from a 1 x 15kg butane gas cylinder using atmosphere ribbon burner with activated carbon filter to eliminate smells and minimise noxious products. There is a low speed tangential fan at the outlet to provide low velocity circulated hot air.

The programme of future work on this project was laid out in the specification as follows:-

(i) Find out from the suppliers of calor gas or LPG etc, the maximum allowable off-take from 15 kg butane cylinder.
(ii) Obtain suitable burner based on above output or manufacture using suitable components.
(iii) Test burner with or without carbon filter to prove results.
(iv) Draw cabinet/ burner/fan assembly.
(v) Assemble prototype model for testing.

No strict price and time limitations were imposed or mentioned in the design brief.

Design and Development

The events which took place thereafter are set out as below.

Month 1

A meeting was held and those present were:

Technical Manager
Drawing Office Manager
Development Manager
Development Engineer

The Technical Manager already had, in his office, a model of the new heater as manufactured by the Spanish company. Prior to this meeting, from the information laid out in the product specification, the off-take from the 15 kg butane cylinder had been determined, and therefore the output of the heater and the life expectancy of the gas bottle were now being discussed.

Air calculations were made which then led to a decision on the fan speed, and it was agreed that a decision on the burner to be used was still dependent on the further lab tests.

A manual control with the existing knob was decided on for the time being and it is to have 3 settings (possibly low, medium and high).

Discussions also took place on the oxy-analyser; a safety device which limits the CO_2 level in a room.

The decision was taken to proceed with the construction of the cabinet so that the fitting of internal parts could be investigated.

The Development Manager was due to start work on the project in Month 2 and his work should be finished by Month 3 . In the meantime there is a progress meeting scheduled in the latter part of Month 2 and the heater will begin field tests in Month 6/7. It is hoped that it will be in full production by Month 17/18.

Month 2

After consultation with various butane suppliers, it has been established that the maximum off-take from the 15 kg butane cylinder is 10 ft 3 /hr (32000 Btu/hr or 9.3 kw) but the generally accepted useable maximum is 7.8 ft 3 /hr (24000 Btu/hr or 7 kw). The prototype DFGH will therefore be built with the following outputs:

	OUTPUT (KW)	OUTPUT (BTU)	RUNNING TIME (HRS)
High	7	23884	28
Medium	5	17060	40
Low	3	10236	66

In the latter part of this month a development progress meeting held attended by the Technical Manager, Drawing Office Manager, Development Manager, Development Engineer and the Works Manager.

A functional model of DFGH which was made in the development workshop was presented at the meeting and discussions were based around this heater. It was too noisy when operating and the development department will attempt to remedy this. The size of the burner and the various temperatures required were also discussed.

The actual manufacturing cost at this stage are unknown as only one off was constructed however the Technical Manager said the target cost to the company should not exceed £50. Everyone at the meeting considered that it would be difficult to keep the actual cost down to that figure. The actual cost to the company would be the deciding factor as to whether the project would continue or be abandoned.

The first thoughts about the intended use of the heater were discussed at this meeting and it was uncertain whether it would attract domestic or commercial use. This was the first occasion the Works Manager was involved.

A week after the development progress meeting, the protoype unit was now operating satisfactorily with a significant reduction in noise level. The next step was to fit carbon filter systems to determine their effect on combustion. The company are buying a combustion analyser so that the levels of Co and

CO_2 can be monitored accurately.

Month 3

Another development progress meeting held attended only by the Technical Manager, Drawing Office Manager and Development Engineer.

The model was still in the development workshop and tests will be carried out to measure the CO/CO_2 ratio with and without the carbon fitters. These results will be compared with those from a competitors model. The carbon filters themselves are bought from a Japanese company and it was felt that this will be a good selling feature.

There have been problem concerning cooling the carbon filters but a metal plate has now have been removed and this may solve the problem.The detailed drawings of this heater will soon be produced.

Month 4 and 5

No further developments.

Month 5

An Industrial Designer has been hired by the company to propose aethetic models and ideas. A heater has been made to the proposed ideas of the Industrial Designer but the Technical Manager was not happy with its appearance. The final colours and appearance will be chosen by people within the company and regional personnel.

The problem of cooling the carbon filters has been resolved and the overheating and cracking has been eliminated.

The heater now operates satisfactorily and next the Chairman of the company will either give his approval or disapproval to the project.

If it is accepted, 10 heaters will be constructed in the development workshop and certain regional areas will be given one each which they can make available for hire. During the time with the regional area, an engineer from that region will keep a strict check on the heater and minotor its progress. The customers will be asked to give their views on its appearance and its suitability to their use. The information received will be fed back to the company where problems can be solved and modifications made if they are thought to be necessary. The various regions therefore carry out field tests and market research to determine whether the product is likely to be a success. If everything goes to plan, the heater will commence proper production in Month 17/18 in readiness for the winter period commencing Month 19.

Month 7

No further developments.

Month 8

The supplier of the fan has ceased the manufacture of this particular type of fan and a different supplier had to be found. As a result the design of the heater had to be changed to incorporate a new fan. This fan is noisy and the

development department are trying to alleviate the problem.

Month 9

A number of modifications have been made to the design.

- the rear cover material changed from sheet metal to plastic.
- carbon filter securing method changed from brackets to a circular ring.
- flame guard changed from black to chrome finish. Also originally the guard was only around the heat zone, but now the complete front panel changed to a wire mesh.
- the depth of the heater shortened to improve its appearance so that it looks more compact and neat.
- at the bottom of the front panel of the heater a wire mesh and a filter has been added to ensure there is clean air intake by the fan.
- controls changed from top panel to bottom of the side panel.

The Chairman has given his approval and the development department are now producing 10 heaters. The drawings have also been completed now by the drawing office.

The calculations show that the heater was still within the originally set target price of £50.

Month 10

No further developments.

Month 11

10 heaters have been built and sent to certain regions for trial tests and hire etc.

Months 12 and 13

Heaters undergoing field tests.

Month 14

Regional personnel quite impressed with the new design and their feeling is it will sell well. However the TM feels that due to the relatively mild winter, these heaters did not undergo rigourous field tests as they had hoped. So the relevance of the tests are consider not to be highly significant.

Because of unsatisfactory field tests the full production of these heaters has been postponed now until Month 28/29 (summer period), in readiness for Month 30/31 (autumn period) originally it was intended that production would commence in Month 17/18.

The Technical Manager said that he was not sure whether the target price of £50 was still applicable, because only 10 heaters constructed in the development workshop and it was difficult to estimate the actual production costs. However in order to minimise the costs Value Analysis exercise will be carried out in due course.

HA have acquired premises and as a result of this the offices and the workshop

facilities will be moved to new premises in the latter part of Month 14. These premises are only about a mile away from its present site.

Also a considerable reorganisation has been carried out in the firms structure - see Figure Apx 3-2 for new organisation chart.

A few changes have been made on the heater:

- front panel changed from a complete wire mesh to part sheet metal panel and part mesh. Now top of the panel is mesh and bottom part is solid except for a small piece of mesh to allow air for the pilot-light.
- controls repositioned again from the bottom of the side panel to the top panel.
- the depth of the heater shorterned yet again. Sales department of the company have been promoting the new design and it is claimed that local education authority is quite impressed with it and would like to buy large quantities of these heaters.

General - observations

The project has not been completed yet; it will undergo field tests again in the winter period and then in Month 28/29, if the tests are satisfactory, the heater will be manufactured and sold commercially. The manufacturing date had to be postponed by 12 months as the development programme did not run according to plan. The unexpected delay in the development programme was due to a number of reasons:

(a) problems with the supplier of the fan for the heater - the company stopped making the existing fan - as a result a different supplier had to be sought. This also entailed modifications to the design of the heater.

(b) the development programme devised initially, was over-ambitious, without any allowance made for unexpected problems or delays.

(c) the development engineers working on 4 or 5 projects simultaneously and therefore could not justify 100% involvement on this project.

(d) field trial tests were of short duration and due to the fact these were carried out during the course of a mild winter - did not give accurate results.

(e) personnality clashes between the Development Manager and the Technical Manager did not assist the situation.

(f) numerous modifications carried out which also delayed the whole development process.

2 The production department did not actively participate in the design and development process. Only on one occasion the Works Manager was present at the development meeting. Otherwise production was not consulted or involved during the course of the project. Although the minutes of the meetings were circulated widely and as a result production personnel were aware of the events taking place. As the majority of the manufacturing work is sub-contracted out the production members feel it is unnecessary for them to get involved. They are only concerned with the assembly techniques which will be dealt with by the Works Manager when the design has been finalised. On the manufacturing side the Drawing Office Manager claims they have full

knowledge of sub-contractor's facilities, capabilities and limitations.

3 The company has some significant gaps in their organisation.

(a) there is a need for a competent and imaginative Industrial Designer - who can continually come up with new creative asthetic designs.

(b) Even more pronounced there is a need for a specialist Production or Methods Engineer - who can work closely with the existing design and production personnel and improve the assembly techniques. This work at the present moment is carried out by the Works Manager who due to his training, background and perhaps due to his responsible position is unable to contribute significantly in this area.

4 No formal standardisation proceedure exists and this is carried out informally by those involved, through their own judgement and initative.

5 A large number of modifications were carried out. For example those involved had a great difficulty in deciding on the arrangement of the front panel and positioning of the control knobs. Perhaps if an expert Industrial Designer was involved he would have been able to prevent these continual changes of mind. When decisions on the control knobs were being made; no due consideration was given to the Ergonomic aspects.

6 The management claim to hold regular Value Analysis exercises on their range of products. The researcher has yet to know of one or see one held during the course of his involvement over a two year period with the company.

7 The method of operations in the company is both formal and informal. It is formal that all the drawings, materials and parts lists are prepared by design and passed to the production department and any changes made thereafter have to be formally made through an amendment note. However it is informal in that everyone can consult anyone without following a pre-determined channel. It seems to work quite effectively because the organisation is quite small and there are no significant personality clashes. The informal dialogues are quite common and frequent without any concentiouness of status.

8 The management claims to carry extensive market research prior to initiating a new product design process, although no such data on this model was readily available. However such data on previous products was available and which supported the managements claim. On the otherhand in Month 2 during the course of the meeting there was a degree of uncertainty whether this heater would attract commercial or domestic markets. This indicates that the company did not clearly define the market it was aiming for and also the fact whether there was a market for this product. The data therefore suggests that the company commenced this project based on notions and opinions of various individuals rather than on any factual data.

9 The organisation structure was changed significantly during the course of the project in the Month 14. See organisation chart before and after the changes - Figures Apx 3-1 and Apx 3-2. After the change

the Drawing Office became under the responsibility of the newly appointed Manufacturing Manager The Works Manager also reported to the new Manufacturing Manager. The Technical Manager claims this relieves him of the production drawing office so that he can devote greater time to new product developments.

10 The company is very fortunate in the fact it can carry out extensive trial tests on its new product designs, through its hire set-up, before commiting itself to full production. Hence the risk element regards product failure is considerably reduced.

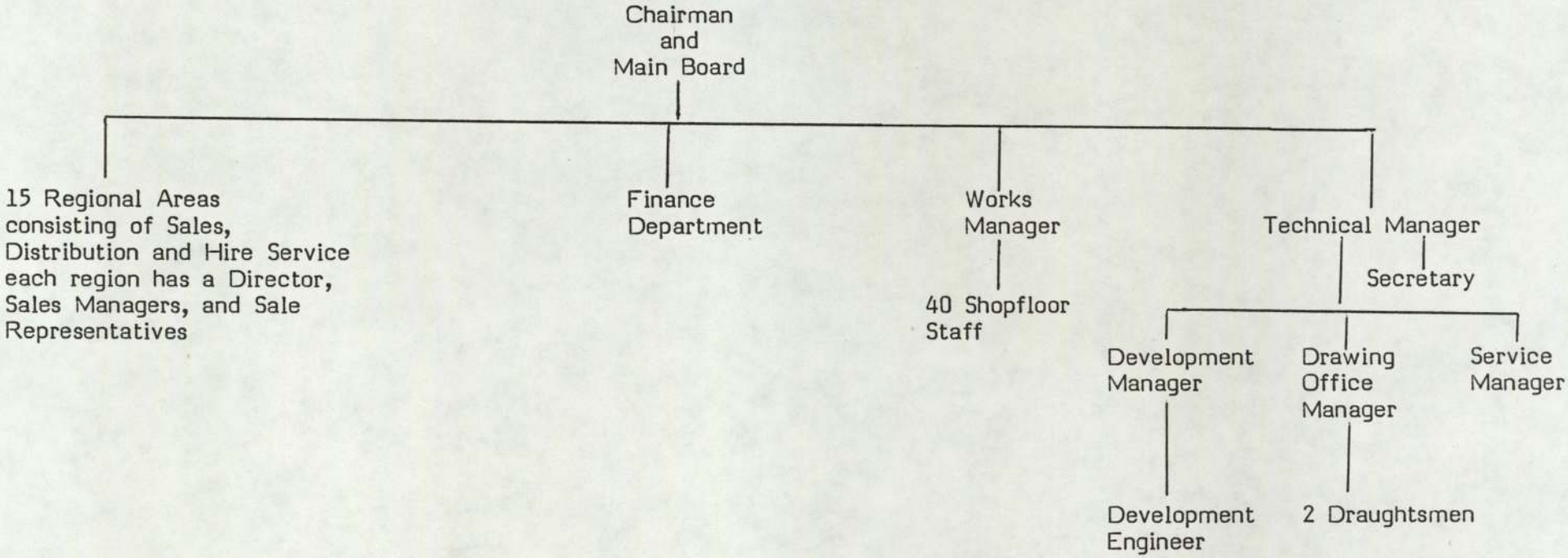


Figure Apx 3-1 Simplified Organisation Chart of HA Limited - Before Re-organisation

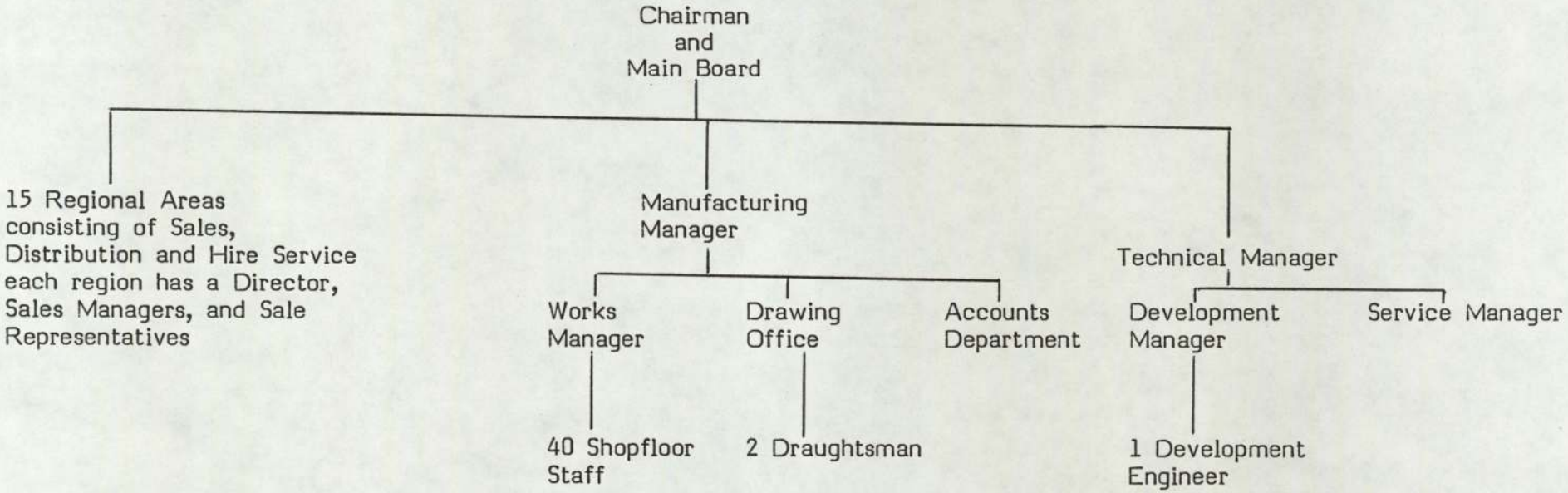


Figure Apx 3-2 New Simplified Organisation Chart of HA Limited

Appendix 4

WF LIMITED

WF Limited with a workforce of 65 is engaged in the fabrication of wire products such as wire baskets, crates and trays. About half of the company's products are designed specifically to customers instructions and as a result it has significant input regards the functional aspects of the product design. The remainder are standard range of products, which are marketed by the commercial department. The firm takes a flexible and informal approach for it, new product development, with constant liaison with prospective customers.

Typical design process on a standard product from its inception to manufacture is as follows.

Product Specification

The Commercial Director, who also performs a role as a designer, is constantly in touch with existing and prospective customers in order to determine their future needs. Once sufficient market data is collected he analyses it and discusses the results with the Production Director (who by training is a Production Engineer). Between them and with the help of the Managing Director they devise a product specification, which is partly written and partly verbal. The specification includes details such as size (outside and inside dimensions), size and material of wire to be used and type of finish to be applied etc.

The specification includes sufficient details for the draughtsman to embark on the design process under the guidance of the Commercial/Technical Director.

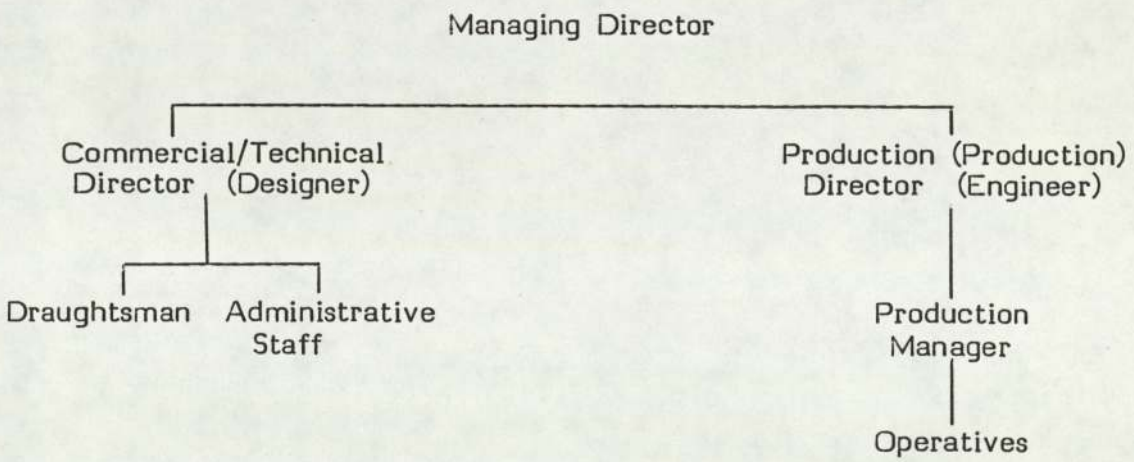


Figure Apx 4-1 Simplified organisation chart of WF Limited

Design and Development

Initial ideas and sketches are converted into comprehensive drawings to facilitate manufacture of models/prototypes. Prototypes are fabricated by the production department, and therefore are programmed into production schedules. Once typical models are complete, the Commercial Director takes them to the existing/prospective customers for their approval/comments etc.

All the comments are carefully analysed by the Directors and if necessary changes are made to the product. Again if required, the modified version of the product are shown to the prospective buyers. When the Directors of the company are fully convinced that all the features are incorporated in the new product design - they initate design of the tools. These tools are designed within the firm but are sub-contracted out for manufacture.

When all the necessary tools are complete, a trial run, using production facilities are carried out. Yet again, samples of the new product as produced by the tools are shown to the prospective customers for their approval/comments regarding the design as well as the price.

If everything goes according to plan, the production commences. The commercial department simultaneously engages in the marketing of the new product.

General

WF Limited is small enough to adapt quickly to customers needs, yet it is large enough to have recources and skills to engage in efficient design and manufacture of wire fabrication business. The management and the staff work in an integrative manner which usually results in effective performance of the design work. Being small in size, everybody communicates on an informal basis which leads to a good and effective design process.

Appendix 5

DHCA LIMITED

DHCA Limited was founded, in 1826, close to its present works it started as a foundry employing fewer than ten people and currently it employs 930 people.

The firm's basic knowledge of ironfounding brought about its entry into the gas cooker field. This was during the 1890's. Cast iron cookers were made until the early 1930's.

DHCA produced a radiant-type gas fire as early as 1905. In fact the management of the company claims to be the first to market a gas fire with five separate radiant controls. The numbered dial control enables each panel to burn separately.

The company has established a reputation for high quality, good design and technical innovation. For example, DHCA manufactures a comprehensive range of built-in and free-standing models. One such model launched in 1980 was the first gas oven to incorporate microchip technology in the automatic timer unit.

This feature is also incorporated in new built-under oven/hob which in 1982 received the blue ribbon award at the Ideal Home Exhibition as one of the best new products on show. The company have won three previous blue ribbon awards.

The company has recently acquired another gas and electric cooker business and intends to set up a production facility at its Midlands works to manufacture the scottish company's gas and electric cookers, hotplates and built-in ovens.

These products will complement and extend DHCA's existing range of domestic cooking applicances.

Organisation

The company is divided into 5 sections each section led by a director - see the organisation chart. The two main areas of interest to us are the Technical function and the Production department.

> Technical department: This is sub-divided into four sections namely, Works Engineering, Quality Inspection and Design. The design department is further split into smaller sections again as illustrated by the diagram. The drawing office consists of one Industrial Designer, he deals with the aethetic aspect of the new product designs. The management constantly look up to him for creativity and original ideas on new models. The design engineers who generally take over the project after the Industrial Designer and transform his ideas into functional products. The development engineers and model shop personnel work closely with the Industrial Designer and the design engineers to change their ideas into practical propositions. The Production Co-ordinator usually fits into the design activity by ensuring designs are produced in collaboration with production departments. The Production Co-ordinator is the key person at the design/production

interface by ensuring that drawings are issued to production department, checked and planned for manufacture.

Production department: Under the leadership of the Production Director, production function operates with the aid of the production managers and assembly managers in addition to this Production Engineering Manager plays an important role in the design process by co-ordinating closely with the design department throughout the design process to ensure that the majority of the problems are resolved at the drawing board stage. When products are designed and planned for manufacture the methods engineers get involved during the pre-production run to ensure assembly techniques are carried out in the correct and most economical manner.In this case the design process for new gas fires is described.

Product Specification

It was agreed at a board meeting to introduce new models of gas fires to replace existing ageing products.

This decision was taken because:-

(a) it is the company policy to review products every three to five years.
(b) there was a need to eliminate some technical problems with the existing models.
(c) there had been a change in customer taste.

During the initial board meeting the Technical Director, was asked to commence the design process and give a date of possible launch. He and the Design Manager discussed the basic parameters of the new product and this information was passed on to the Industrial Designer and the Design Engineer. This was all done in an informal manner with no written design brief.

The basic information conveyed to the design team was that two new gas fires (GF 3 and GF 4) are required to replace two existing GF1 and GF2.

Brief outline of the existing fires:-

GF1 This design used a standard fire radiant heat exchanger unit and the appearance is one of wood effect.

GF2 This fire has a 'brass' appearance for decorative purposes but does not utilise a standard heat exchanger unit. Instead, heat is given off using a 'brick' arrangement with a visual coal-effect. It therefore does not have any radiants.

It was decided that the two new gas fires (GF3 and GF4) would be of the same basic internal design with only external differences to separate them.

GF3 Ordinary radiant fire with a canopy.

GF4 Radiant fire but displaying coal effect again with a similar canopy as GF3.

The basic idea behind the introduction of the new gas fires was to have the same outer appearance as GF2 whilst using the standard heat exchanger unit of GF1.

Design and Development

Based on the information provided by the TD and the DM, the designers gave verbal instructions to the model shop to construct a fire using the GF1 heat exchanger and the GF2 body shell.

The series of events which took place during the design and development process are set out below.

Month 1

A working model was constructed in the development workshop after collaboration between design and development engineers. Various problems cropped up during the construction of the model and modifications had to be made.

(i) the canopy was too low and covered part of the radiants and therefore the fires efficiency was reduced. After verbal discussions between the TD, DM, D and Development Engineer (DE) it was decided to shorten the canopy.

(ii) After the first modification it was found that the canopy was too wide and this was duly narrowed. At the same time the control switch for the fire was repositioned higher than the equivalent position on GF1.

(iii) A fender was added to the front vertical face of the base.

Please note as GF3 and GF4 are identical except for the addition of coal effect on GF4, the above modifications apply to both fires.

The modification necessary were decided upon and carried out in an informal and verbal manner. The arrangement worked successfully and effectively because of good communication between those concerned and a lack of apparant personality clashes. All the decisions were made with one aim in mind - the product.

In parallel to this the designer proceeded with production of detailed drawings of the fires.

Month 2 - Week 1

A meeting was held to outline the following objectives:

- to decide which drawings can be issued to production for tooling.

- to discuss any other production queries likely to occur in the foreseeable future on these fires.

- to estimate the time scales concerning buying materials and tools from outside.

- to estimate time scales concerning commencement of production.

- to determine and set target dates for component production.

- to determine the degree of standardisation possible on new products.

Those present at the meeting included:-

Production Director
Technical Director
Design Manager
Designer
Purchasing Manager
Production Co-ordinator
Production Engineering Manager
Development Engineer

A chart of components (prepared beforehand with the help of the design department) was produced by the Production Co-ordinator and was displayed and discussed in detail with those present. It was mentioned that there was to be a degree of standardisation using existing parts from GF1 and GF2, but this was done in an informal manner and no set guidelines were drawn up concerning standardisation. Although the chart was produced by the Production Co-ordinator and the Designer, other people such as the Technical Director and the Design Manager, knew of its existence but not of its contents. The other people present at the meeting knew vaguely about the purpose of the meeting but did not know any details. This meeting was the first involvement of the Production Engineering Manager and the Purchasing Manager. The Production Director was involved in the project from the initial board meeting.

Month 2 - Week 2

In the intervening period since the meeting in Week 1, a few extra parts have been added to the component list.

The component specification has been drawn up by the Designer and this lists all the parts of the new fires.

Also in this week there was a discussion concerning the proposed packaging of the fires. The people present were: Purchasing Manager, Production Controller, Designer and a representative from a Packaging Manufacturers. The representative was told verbally about any items which were fragile (therefore requiring extra attention) and was also given dimensions from the proposed design. A one-off 'prototype' will then be produced by the packaging firm and tested for suitability.

Month 2 - Week 3

A progress meeting was held attended by Production Director, Technical Director, Production Engineering Manager, Production Co-ordinator and Designer. The list of people shows the close working relationship between the design and production departments during the design process. The objectives of this meeting were to discuss the progress so far and also to sort out any possible problems.

The Production Co-ordinator, prior to this meeting, produced two component charts, one for each new design, rather than one general chart. The Production Engineering Manager produced the dates of deliveries of various parts tools which he had obtained from outside manufacturers.

A modification had been carried out on the five cowl, which involved shortening it; there was misunderstanding between the Technical Director and the Designer concerning the exact nature of the alteration; which was sorted out by the Development Engineer, who was responsible for carrying out the modification (Development Engineer was called into the meeting to explain this and left afterwards).

The Production Engineering Manager was concerned with the size of some components (such as canopy and fender) which would require a long time for tooling, deliveries and sorting out various problems.

Also discussed at this meeting was the finish of the front of the gas fires.

The Production Engineering Manager at the end of the meeting was issued with preliminary drawings by the Designer, so that estimations for tooling and quotations could be made.

NB All the above areas concern both GF3 and GF4.

Month 3

Changes made to GF3:

- it has been decided that the guard for the radiants will have a bright chrome finish, as opposed to dull finish as specified previously.
- the canopy will have a different texture colour than that of GF4.
- there are problems concerning the chrome finish of the reflection below the radiants. The chrome gives a mirror finish and it is found that this is easily scratched during assembly. If the scratches are apparent, the component is usually rejected and the rejection rate is high at the present time on the previous models. It is possible that finish will change either to a dull, lacquered coloured or a textured bright finish.
- the ignition switch was changed to a black finish.

Changes made to GF4:

- the guard for the radiants is to be finished in black in an attempt to cut costs. Previously it was to be a bright chrome finish.

- a reflector below the radiants has been added to keep heat away from the glass fibre 'coal-effect' and reduce the chance of damage. It was considered that this also improves the appearance as well.

- the body colour was altered from brass to grey, as were the side panels.
- the fender and the canopy was finished in pewter. The reason for the colour changes was to maintain a price differential between the two models. The GF4 to be sold at higher price than GF3.

Changes applying to both models:

- the shape of the ornamental 'figure' on the outer caps to the front panel was changed slightly. This change was carried out by the Industrial Designer to enhance the attractiveness of the fires.
- the shape of the pattern printed onto the side panels either side of the radiants was also changed slightly.

The two new models with the above modifications were built in the model shop. These were sent to Watson House for technical examination to ensure they met the required standards (Watson House is an organisation where all the new gas appliances in the UK must be sent for inspection and approval. They thoroughly test the appliance to ensure it complies with the relevant technical and safety regulations. Only when the appliance has been approved by the Watson House, that it can be made available commercially.) It usually takes about two to three months for Watson House to carry out necessary tests. DHCA Limited usually does not alter the fires significantly until their return, when modifications will probably be carried out if recommended by the report.

In the meantime there is a problem concerning the flexible drive from the control switch to enable the fire to be turned ON or OFF. The Designer is working on this problem.

All the tooling for the fires has been ordered, which is rather a large risk as modifications imposed by Watson House could render some parts obsolete.

Month 4

The problem of the flexible drive to the ignition switch has been solved as the suppliers of the flexible drive has improved the design using a better idea.

Still a considerable debate amongst the design team and the management regards the types of finish which should be used on the fires. The current feeling is GF3 to be pewter and GF4 to have copper textured finish, but these are not finalised and are liable to be changed in the future.

A meeting was held in the latter part of this month to discuss the progress on the tools and any other changes which have been made.

The people present at the meeting were; Production Director, Design Manager, Designer, Production Co-ordinator, Production Engineering Manager, and a

Buyer.

Some of the parts and the tools ordered from outside have been delivered.

Investigations were still being made on the finish of some parts, and it was decided that similar parts with a differing finish would have to be given different part numbers.

A name plate and a data plate providing specifications of the fires were added to the designs.

It was decided that a pre-production using the actual production tools would commence at the beginning of Month 6.

Month 5

The GF4 was constructed (with 20-30% of parts as for production) by the PC. The flexible drive problem previously thought to be resolved was still causing difficulties. The other fires are still at Watson House undergoing tests to meet the British Standards. If any modifications decided by DHCA in the meantime, these are conveyed to Watson House and are usually carried out at their premises by a development engineer from DHCA.

An advertising campaign is to be launched in Month 8 regarding the new fires. They therefore have to be in production by this date and in stock at the warehouses. The management has decided that this will happen whether or not the designers have been passed by Watson House. This obviously incorporates a risk in that the fires may have to be modified whilst in stock at the warehouse, and the extra costs involved.

It is apparent that once the company have set a target, this target is always achieved although extra cost may be incurred. For example, the tooling was ordered before it was known that the parts produced by that tooling to be the ones used for production.

The specifications for the assembly shops and the spare parts lists for the Gas Boards are both in the process of being prepared.

Month 6

The fires are still continuing their tests at Watson House. The mechanical tests have been completed; they are now undergoing performance tests.

There are still problems with the flexible drive and these are still under investigated.

A modification has been made to the back of the fires, the backplate is now rivetted rather than screwed in position as this will make it easier for both assembly and painting. This suggestion has been made by the Paint Shop Manager and the Methods Engineer. The modification applies to both models.

At the end of Month 6 and the beginning of Month 7, when there is works shutdown, the Designer and the Production Co-ordinator will construct fires on the production line using the components produced by production tooling.

In the latter part of this month the management team meeting held to choose

the colours, final designs and general appearances of the two gas fires.

The people present were:

Managing Director
Technical Director
Production Director
Sales Director
Financial Director
Commercial Plant Director
Industrial Designer
Design Manager
Commercial Manager
Consulting Cost Manager

5 different variations of GF3 fires were displayed of which one was to be chosen for production. Only one GF4 fire was on display.

The GF4 gas fire was accepted as displayed with coal effect and pewter finish canopy.

The choice of GF3 was narrowed down to two alternatives but these couldn't be separated and it was decided to let about 50 representatives of the workforce make the final choice. The two final alternatives were:-

(a) a copper textured canopy with a plain matt finish reflector.
(b) a copper textured canopy with a copper textured reflector.

Month 7

A pre-production run of GF3 and GF4 has started.

The Watson House have completed their tests and their comments have been received.

Some modifications suggested by Watson House had to be carried out and they were:

- the fixing of the plate on which the 'figurine' is produced had to be improved (this applied to both fires). An extra securing bracket was used to overcome this problem.
- the worked of the instructions on the label had to be improved.
- other minor modifications advised by the Watson House report were carried out. The remaining areas were satisfactory.

It came to light that the Designer was unaware of the lack of final decision on the appearance of GF3. He was very concerned about the decision being made so late that it would be hard to obtain raw material before full production commenced. He felt the decision should been taken perhaps 5 or 6 weeks ago. As the Designer wasn't present at the management meeting in Month 6, there was obviously a lack of communication somewhere.

Apart from this there are still some problems with the flexible drive, but the Designer was convinved that it would be resolved before production started.

Month 8

The Development Engineer has compiled a report to send back to Watson House following their report and advise on modifications. This constitutes mainly answers to their queries and solutions to the problems raised.

The GF3 and GF4 fires are now on the production lines and made from production tooling.

An inspector from Watson House visited DCHA Limited to see if their recommendations had been implemented and also watching out for any other problems.

In fact there was a small gap between panels at the top corner of the canopy which he said had to be filled. This was duly carried out on the production line.

In an interview with the Designer, it became apparent that he had not received any information about the Management meeting held in Month 6, until two weeks later when he personally had to go and see the Technical Director to obtain it. He then learned of the indecision between the two GF3 finishes and he said the final choice between the two fires was made by the Senior Management only. No employees were involved or consulted as was the original intention.

The management chose the fire with copper textured canopy and copper finish reflectors. This was now being manufactured.

He added the modifications requested by Watson House had been carried out.

The problem, which the designer was concerned about, of acquiring raw material for the copper finishing was overcome by multi-sourcing around the country until a bulk supply could be guaranteed from abroad.

Some items of tooling for the canopies which had been delayed 15 to 16 weeks by the outside supplier but these were now available.

Month 9

No changes

Month 10

A few small modifications made. 85 fires per week are being produced. It was hoped the production rate will increase to 120 fires per week; the reason for the lower output at the moment is that the workers assembling the fires have no previous experience with this type of job, and it is hoped that as their experience increases, so will the rate of production.

The supply of some of the parts for the canopy are not up to the required standards and this was due to lack of capacity at the suppliers. As a result of this DCHA are looking into the possibility of alternative sub-contractors.

Month 11

Fires officially launched and sold by British Gas Board.

Month 12

There are still no problems associated with the fires and production now running at 120 fires per week.

The problem of flexible drive still not completely resolved. Investigations are still being made and some fires may have to be recalled from the warehouse for modifications to be made.

Month 13 to 15

No change.

Month 16

Some changes have been made to both GF3 and GF4.

Major Modifications: A new design of manifold has been replaced the existing design.

A change note for this was prepared and formally circulated to heads of departments affected by the change. A number of fires recalled from the warehouse to carry out this change.

Minor Modifications:

- the flexible drive fittings changed from aluminium to steel and they are now crimped in position. This finally has resolved the problem.

- the adhesive for the label has been altered to a more suitable type.

These changes carried out by means of a change note.

Month 17

No further development.

Month 18

The designer said production of gas fire GF3 (without coal-effect) to discontinue shortly, as warehouse stocks are extremely high and the sales of this particular model are not as high as originally anticipated. The production on GF4 gas fire to continue as normal.

Month 19

The production of the GF3 ceased. This model has not yet been withdrawn from the market but if poor sales persist then it will be withdrawn from the market in the near future.

Months 20 to 23

Sales of both gas fires, GF3 and GF4, have not reached the expected levels. The production of GF4 gas fire has also been discontinued.

Month 24

Both models have been withdrawn from the market, with an intention to introduce updated fires in due course.

Observations

A number of observations were made during the course of this project:

1 Management encourages informal 'family' type of atmosphere in the company and attempts to prevent inter-departmental demarktions. The Managing Director and the Technical Director claim this improves communication amongst employees, increases job satisfaction, encourages creativity and leads to a better end product. These claims were generally supported by the design team, Assembly shop managers and the Production Engineering Manager. The designer said the management gave its designers greater freedom and responsibility and allows them to proceed with the design project with minimum of supervision.

In fact co-ordination amongst the employees was excellent throughout the project. In contrast to this there was an incident in Month 6, when senior management held a meeting to choose the appearance of the GF3 gas fire. On this occasion the management failed to convey the outcome of the meeting to the designer. It was in Month 8 when the designer, personally had to go and see the Technical Director to obtain the relevant details. This is when he learned of the indecision between the two finishes on the GF3.

2 Meeting are held on either a weekly of fortnightly basis with design, production and buying activities participating. Minutes of the meetings are not kept, each individual remembers his task and responds accordingly. The management claim this system to be ideally suited. However the incident mentioned in the 1st observation, about the senior management, indicates its drawbacks. In fact the designer in this particular instant was very concerned about the whole incident. Similarly, Production Engineers, Foremen and a few Production Assembly Managers complained that frequently they were not kept up to date by their relevant superiors regards the events taking place at these meetings. Although they were all quite satisfied with the general management of the design process but a consensus of feeling existed amongst them that the minutes of the meetings should be kept and widely circulated in order to improve some of the communication weaknesses.

3 Management sets a launch date and strictly adheres to it even if additional costs are incurred. For example, tools are always ordered at an early stage although later on in the design process changes may be made to the product. This results in changes to the tools, at a high cost. For example, the total tooling cost for this project was £107,000, 21% which was incurred due to modifications.

4 No formal standardisation procedure exists when designing new products, yet a reasonably high percentage (45%) of standard items are used in new designs. This is achieved in an informal manner - the designer attempts to do this based on his experience and judgement rather than through the existence of formal guidelines. However the production department feels that insufficient standardisation is carried out - with

more time and investigation this could be improved thereby reducing tooling costs.

Degree of standardisation:

Model GF3 - Total number of components: 100;
45 of these components are taken from the previous designs GF1 and GF2.
Therefore it incorporates 55 new components.

Degree of standardisation - $\frac{45}{100} \times 100\% - 45\%$

Model GF4 - Total number of components: 129;
52 of these components used in the previous designs GF1 and GF2.
The new design therefore has 77 new components.

Degree of standardisation - $\frac{52}{129} \times 100\% - 41\%$

NB 43 components are shared between the two models.

5 The working relationships between design and production functions is qui te satisfactory. This is further improved by the existence of the Production Co-ordinator and the fact regular weekly or fortnightly meetings are held to ensure optimum involvement by all those concerned. In addition to this free and frequent informal dialogue amongst the members of the two functions also occurs, The members of the two functions enjoy similar status to each other.

6 There is a strong evidence of inadequate marketing input to the product design. From the beginning of the project very little knowledge existed about the market requirements, tastes and trends etc. No market survey was conducted prior to start of the project regards the possible sales or likelihood of its success. This argument is supported by the fact, when in Month 6 at the management meeting, the management decided to carry out a survey amongst its 50 employees regards choice of appearance of GF3 - this survey if it had been carried out would have been biased and therefore unsatisfactory. Because general public would not have been consulted this situation was further deteriorated by the fact that not even the shop-floor workers were consulted. To this date mystery still remains as to what criteria was used to make the final decision. It is therefore, not surprising that expected sales were not achieved and the fires were finally withdrawn from the market. The management claims sufficient information existed about the market - but the lack of success of the products proves otherwise. Also this fact that the company's management does not believe in keeping formal records of events and important decisions made during the course of the project. This means that they cannot refer to any records and perhaps learn from this 'mistakes'. They simply rely on memories of various individuals. These events imply that serious weaknesses exist regards the quality of new products management.

However one significant change which has taken place in the company since the withdrawal of GF3 and GF 4 gas fires from the market - is the recruitment of a Marketing Director.

7 One important factor which lead to good liaison amongst the employees and with the management was the low turnover of the employees and stability of the higher management. The senior management has also remained unchanged for the last 6 years, as a result their policies, methods of operation, and expectations are well known throughout the company. The Managing Director boasts that this has led to good labour relations (no indusutrial disputes for the last 6 years), improved productivity and above all growth of the company even in these troubled recession periods.

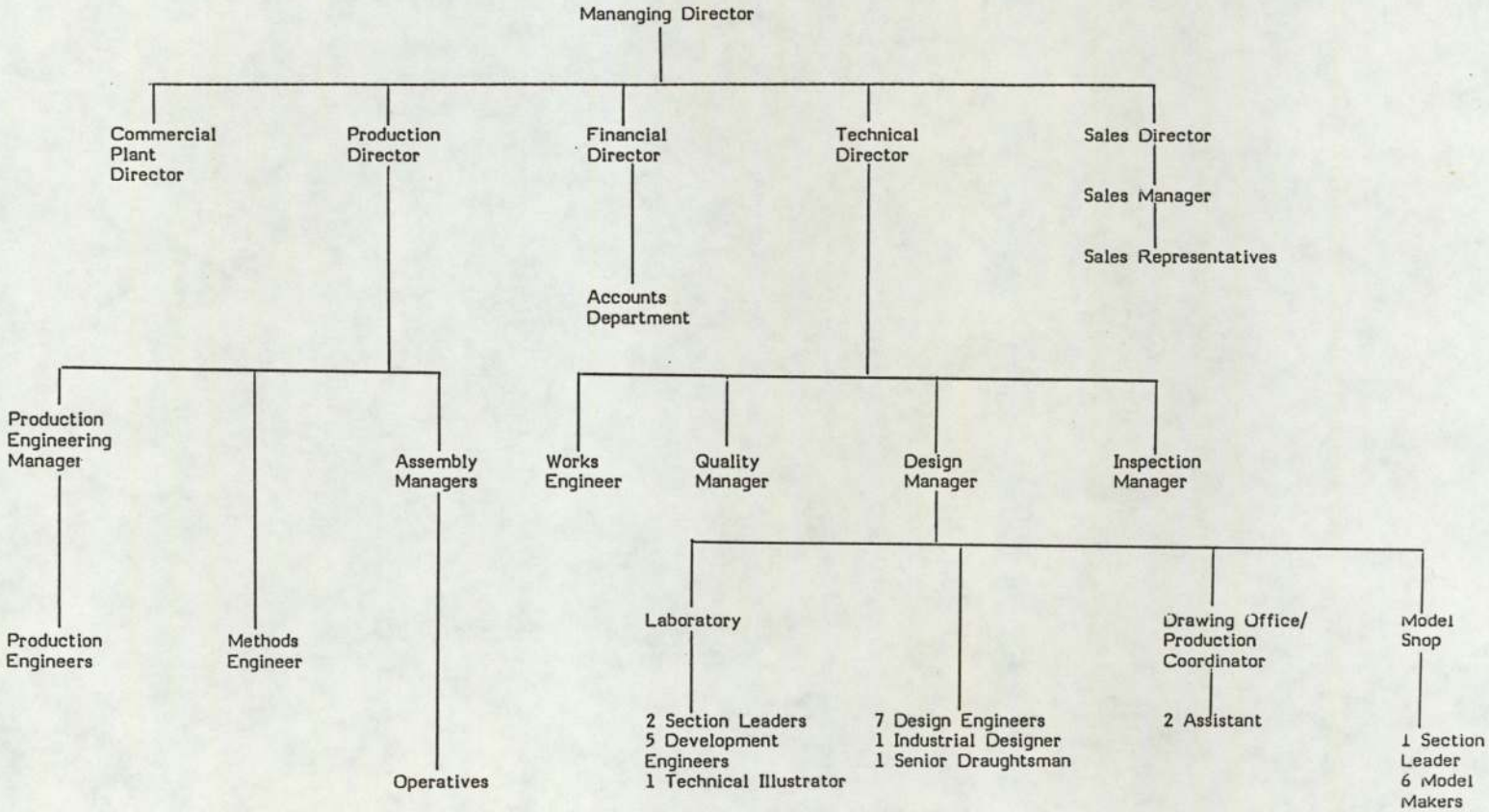


Figure Apx 5-1 Simplified Organisation chart of DHCA Limited

Appendix 6

FPM LIMITED

Company FPM Limited has 650 employees and is involved in the manufacture of a range of food preparation machines. The firm is well established in markets in the UK and overseas and has manufacturing plants in several other countries.

The Managing Director is overall responsible for the operations of the firm at three different locations namely in France, USA and UK. This case study is based on a new product development at its UK manufacturing plant. When the Managing Director is not directing operations at its UK firm the General Manager (who is also the Manufacturing Director) takes over the general running of the firm. Both the General Manager and the Managing Director have been with the firm some 25 years and are engineers by profession and take a keen interest in the product development process.

Under the leadership of these two key men the firm is split into different divisions such as Sales, Finance, Technical and Manufacturing etc. The three functions which are of interest to us in this study are Sales (Marketing), Technical and Manufacturing.

The Sales function is headed by a Sales Director responsible for directing a fairly active sales force as well as assisting the firm in developing new products.

The Technical department is currently headed by a newly appointed Engineering Manager (he was appointed in Month 20 of this project). Prior to his appointment the responsibility for the technical function resided with the Technical Manager (he still retains his position although the Engineering Manager has taken over the majority of the control of running the department). The technical department is further split into according to the product range. Each product range is headed by a Section Leader as shown in the organisation structure. (Figure Apx 6-1)

Finally the Manufacturing aspects of the company comes under the newly appointed Manufacturing Manager (he, like the Engineering Manager was appointed in Month 20 of this project). Before his appointment this function was controlled by the Works Manager(who in fact relinquished his responsibilities for the Production Engineering function to the new Manufacturing Manager but still remains in-charge of the Manufacturing Operations). However the Works Manager is accountable to the Manufacturing Manager. The Production Engineering activities are controlled by the Chief Production Engineer.

This case study describes the design and development process by the firm of a new mincing machine.

Product Specification

There is no regular procedure for the compiling of specifications and the initiation of projects, despite the fact that a considerable amount of design work is undertaken.

In general, it has been found that design projects are started in a very casual manner without written guidelines and with most vague expectations, usually delivered by word of mouth. The overall design effort was found to be unproductive and morale was poor. One design exercise, studied from its inception to its manufacturing phase, highlights some of the events which took place during the course of the design process.

Senior management decided that one product (meat mincing machine) should be replaced. Its existing mincing machine was unsatisfactory in several respects:-

- the chrome plating was peeling off around the feed hole.
- the feedhopper at the feed-hole has a side hole which was too big and a safety hazard as a girl had recently trapped her hand in it.
- the worm feed screw inadequate and its design need changing.
- the whale bone washer required development as its life was being reduced due to heat generation.
- the handle when removed to allow access to the internals of the machine was too bulky and the design needs to be changed.
- the casing of the mincer was at present cast in aluminium and the material used may have to be changed for both cost and durability.
- the gearbox did not perform up to the required standards and the whole design needed to be re-thought.
- there is a possibility that the motor may burn out in certain circumstances when under excessive loading.
- the shape of the pan could be improved.
- the manufacturing costs of the existing mincer was too high.
- the existing design was generally outmoded.

The list of problems indicated a completely new design was required. Because of existing design team was already fully employed, a new designer was recruited. The designer was given oral instructions on the new product requirements by the Technical Manager. No written information was provided.

The series of events which took place thereafter are set-out below:-

Months 1 - 4

The designer familiarising himself with the company's range of products and the problem at hand.

From his preliminary ideas the designer produced sketches and drawings, which were converted into a wooden model with the assistance of the development workshop personnel.

Month 5

Discussions took place about model between the designer and the Technical Manager to demonstrate the line the designer was pursuing. This was then passed to the Sales Director for comments and feedback.

Months 6 - 8

The sales director failed to comment on the model and in the mean time the designer assumed that his approach must be satisfactory. He continued along the same lines and further developed his ideas into a working prototype.

Month 9

The prototype was presented to the sales director - who rejected it as being completely unsatisfactory. In fact the sales director argued with the designer that he never said that the initial wooden model was satisfactory and he should proceed with building a prototype.

Realising that he needed better information, the designer attempted to communicate directly with the sales director. This brought rebuke from the senior managers in the design department who insisted that they should be involved in all communications.

However, it was now realised that it was in everyone's interest to have some kind of written specification.

Month 10

A meeting was held to devise a specification and discuss in detail the progress up to now. This meeting was attended by the General Manager, Development Manager, Chief Production Engineer, Technical Manager, and the Designer. The details of the items discussed at this meeting are as below:-

- It was clarified that three different sizes of machines is to be produced namely 12, 22 and 32.
- All three sizes of machines to have same base casting and motor carcase dimensions.
- They all to have the same gearbox and gearbox bracket, the gearbox being standard bought in unit.
- The horsepowers of these machines to be
  1 hp for size of 12 machines
  2 hp for size of 22 machines and
  3 hp for size of 32 machines on 3 phase or 2 hp on single phase.
- the rpm to be 1420 on 12 and 22, and 2850 on size 32.
- the barrel housing to be in aluminium grade LM6 and the pattern is the same for all three machines. This casting to have two diameters of bore, namely a large bore for the 32 machines and a small bore for the 12 and 22 machine. There will be one pattern and two core boxes needed.
- the prototypes to have parallel bore barrels since this produces a simpler machine. Whilst the attraction of a parallel barrel have disappeared but it gives a bigger diameter at the feed end, and is preferable for this reason.

- the machine hoppers to be in LM6.
- the drive from the motor to be by timing belt and this would have round teeth. In all cases the motor pulley would be the same, but when using the higher speed motor on the 32 machine, the driven pulley would need to be larger.
- the samples of the new injection moulded plastic worms have arrived and the quality is excellent. So these type of worms to be included on the new series of machines.
- the safety guard to be ball burnished aluminium casting, supported on pillars.
- the sample gearbox used on the previous prototype is rather noisy and it needs to be insulated to keep the noise to acceptable levels. This can only be devised on further trials on the prototype.
- the production on new machines to start in Month 22.
- prices of these machines yet unknown and these should be determined as soon as possible.

The designer was asked to proceed along the above guidelines and produce necessary drawings and proto-type model. Also agreed that the project should be strictly monitored through monthly meetings.

Month 11

There was still a considerable degree of uncertainty regards the precise requirements from the new machines. Also the fact not everybody was in agreement as to what are the real problems with the existing range of mincing machines and what line the company should pursue in future.

Some of the extracts from the meeting held this month are as below:-

General: The meeting stated that it should be looking for a higher speed machine. The motor should run cooler than the present machines. The plastic worm and spiral barrel should be fitted as standard. The feedpans should be larger than present machines, especially on the 2 largest sizes of mincer.

Size 12 Machine The existing feedpan on this is satisfactory in size, and the thumbscrew fitting is acceptable.

The size 12 is not normally used continuously and have had no complaints about the heat build up from the motor.

Export department certainly requires a 12 size machine and again intermittent operation is quite satisfactory. They would prefer a stainless steel casing but this would possibly push the price too high.

Gearbox Design The company's existing gearboxes should not be used on new machines because these have been found inadequate in service.

32 versus 22 Size Home sales department report that there is a trend towards the larger machine ie 32 size on the home market, and the 22 size is not so popular.

There was a feeling that the 22 size would in fact become obsolete on the home market. It was stated however that at present it is probably the most popular size on overseas markets, and its lack of popularity in

our range might be caused by the fact that the company's price for the 22 and 32 are too close to each other. This is caused by the fact that both machines have identical gearboxes and other main components.

New Designs The latest suggestions for a new design were outlined by the Designer. He said it was intended to use a standard single reduction spur gearbox which as to be bought from an outside manufacturer. The motor would be direct coupled thus eliminating a primary belt drive with its maintenance difficulties.

The noise levels would need careful attention and trials and possibly sound insulation would be necessary to achieve a satisfactory level.

The new designs which are to be signated as 'Mark II' are being drawn up in detail for evaluation and costing. The company was concentrating initially on the 32 and 22 sizes, because there was still a little doubt as to the correct policy on size 12 machine.

Month 12

'Mark II' design of machines

Work was proceeding as quickly as possible upon a new range of machines and a bar chart was produced giving a production prototype completion date of Month 18. This date was only applicable for size 22 and 32, since there was still a considerable degree of uncertainty on size 12 machine.

Gearbox manufactured by a Danish company seems to be the most appropriate to the FPM's requirements.

Worms, Barrel The present thinking was that the barrel should be shell moulded so that sufficieintly accurate bore in the barrel can be achieved to eliminate machining operation. The clearance between the worm and the barrel has been checked on a variety of competitiors machines and was 0.020" to 0.030" per side.

The difference in performance between taper and parallel worms was not significant. In fact it was better to have a parallel worm, since one achieves a more satisfactory feed opening and actually a larger diameter worm at the feed end, compared to a taper worm.

Motor The motors from two companies are being evaluated to determine the suitable one.

Month 13

Motors The motors from two companies are still undergoing field tests to determine the most suitable one.

Cost of new range of machines Full detail drawings are due to be completed at the end of Month 14 and the management was asking for a rough price to be given by the first week in Month 14 for size 22 and 32 machines.

Size 12 Design The designer proposed a double reduction drive using a new timing belt. The life of such a drive very adequate for this size of machine. There are advantages in that there will be no oil bath and the company should have no sales problems.

NB This was the first time the Sales Director asked for the copy of the minutes of the meetings to be sent to him.

Month 14

New Designs of Size 12 machine

A drawing of the proposed new design of size 12 was shown to those present at this meeting. The physical dimensions of this machine were discussed and it was realised that it was smaller than the existing machine.

The timing belt on this machine will be approximately 2/3rds the cost of the proprietary gear box.

NB This was the first instance when the Sales Director was present and he refuted a number of ideas previously discussed such as motor horsepower and speed, as well as the safety features. The drawing indicates feed back diameter to be 2.125" but however it was felt that rumours exist that on the continent there was a requirement now for 40mm (1.57") diameter hole. Although nobody was certain of these dimensions which are paramount for safety purposes.

Note: the General Manager did not attend this meeting.

However when three days later the General Manager received a copy of the minutes of the meeting, he immediately called an another meeting attended by the General Manager, Chief Production Engineer, Technical Manager and the Designer.

Note: The Sales Director did not attend this meeting.

The purpose of this meeting was to discuss and clarify the details on the 22 and 32 size mincers. The design so far was too costly, and the meeting was held in an attempt to lay down a specification to guide the designer in achieving a cheaper design.

The extracts of the details discussed are set out below:

Cost

The lowest horsepower machine in the 22 size range should have a 1 horsepower motor and the works cost should be no higher than £350.

Horsepower and Phase

The horsepower decided on the motors were:

1 hp size 22 single phase
2 hp size 22 single phase or 3 phase
3 hp size 22 single phase or 3 phase.

The one and two hp machines in single phase could operate from a 3 pin 13 amp plug.
The three phase, two hp motor would need to be hard wired.
The three hp single motor, and three phase would need to be hard wired.

Worms To be plastic, injection moulded and parallel.

Barrel High tensible heat treated aluminium alloy, parallel bore.

Nose Cap Aluminium alloy high tensible heat treated.

Gearbox To cater for three hp maximum. This may be a worm gearbox with primary timing belt, to give facilities for speed variation and as an aid to noise reduction. There are other alternatives such as timing belt by our own gearbox, and other proprietary gearboxes. These are being evaluated.

It was emphasised that the company should avoid putting themselves in the hands of only one supplier, and must ensure dual supplies, of gear boxes are available.

Cladding This was to be in stainless steel over the main body.

The minutes of this meeting were widely circulated to the managerial staff throughout the company with a note saying that if anyone disagrees with these parameters, they should contact either the designer or the Technical Manager immediately since this project was now of the utmost urgency and any waste of time would have serious repercussions.

The designer was asked to proceed along the above laid down guidelines and produce the appropriate drawings as soon as possible.

Design and Development

Month 15

The machines are now being designed using a worm gearbox and primary timing belt drive from the motor. Spur gears directly driven from the motor were found to be much too nosiy. Also from the horsepower sizes laid down in the specification, different rpm's for motors and worms were determined.

Dual supply of Gearboxes The designer has been looking into different gearbox design; whilst an Italian gearbox design was preferred, the designer attempting to design the machine was such a way as to accept an alternative gear box design by an another company. This was in case the Italian company ceased to supply the gearbox in future for any unforeseen reason. This months meeting was only attended by the Designer, Technical Manager and the Development Manager.

Month 16

All the parts being further developed slowly. There are still numerous problems which need to be resolved.

Month 17

This month's meeting was attended by the following, the Managing Director, General Manager, Sales Director, Works Manager, Chief Production Engineer, Development Manager, Technical Manager and the Designer. The extracts of the meeting are as set out below:

Sizes 32 and 22 machines The Managing Director suggested that we might consider production of a size 32 only, and this could run slowly for the lower throughputs with 1 hp motor. This would lead to economies in manufacture. The Sales Director claimed that the 22 was the traditional High Street Butchers machine, whereas the 32 was more of a supermarket design. There was little different now in works cost between 22 and 32, and the output was not very different. The output from the 32 should increase with the better new design with the one piece barrel.

For the present, we should proceed with the 22 and later 32 machines for tests and consider whether we might discontinue the 22.

These machines have the same fabricated structure. The top cover was desgined in mild steel, but may be able to make this from plastic.

Programme for prototype 22 and 32 Machines was devisewd during this meeting snd is set out below:

Initially we should concentrate on the 22 machine.

By the 8th day of Month 18	- 3 sets of 22 parts are to be ready except for the cast iron end caps.
By the 17th day of Month 18	- the barrels should be machined for the three 22 machines.
By the 19th day of Month 18	- three 22 machines are to be completed.
By the 9th day of Month 19	- the 32 barrels for 3 prototype machines to be complete.

Month 18

This month's meeting was attended by all those present at the meeting of month 17 except for the Sales Director.

The prototype programme was going as scheduled in Month 17.

However the styling of the machines still remains undecided and the opinion of a Consultant Industrial Designer was to be asked for.

The skeleton design of the size 12 machine has been produced by the designer but it needed to be simplifed and perhaps the materials used changed to reduce the works cost.

Month 19

The tests on the first prototype mincer carried out. There were some problems with the machine stalling during its operation. On two occasions the 13 amp fuse was blown because the motor brought from an outside supplier takes full current load of 18 amps not 9 amps as originally thought.

Now a new motor supplier was to be found which provides the required current load.

The Consultant Industrial Designer proposed a number of aesthetic styles for the mincers but these were considered to be unsatisfactory.

Month 20

Tests on the prototype machines are continuing with a new motor. However the motor has a tendancy to overheat during prolonged mincing tests.

This month a new Engineering Manager recruited, he is to head the design and development department. The Technical Manager however still retains his present position.

Month 21

Due to unsatisfactory performance of the prototype machine, the design brief revised yet again. The barrel and the body construction changed to overcome some of the difficulties experienced during tests.

Month 22

The production was originally scheduled to commence this month - but due to the difficulties experienced during the development it was still uncertain as to when it will start.

Month 23 - 27

There are a considerable number of changes which are being made and further tests are being carried out.

Month 28

The tests are now satisfactory. The designer was now preparing detailed drawings.

Month 29

The detailed drawings completed and formally handed over to production engineering department. They were instructed to commence production run by Month 31, as this machine was to be displayed at an exhibition in this month. The production department were allowed one week between receiving the drawings and commencing the pre-production run. Due to the lack of time available, the pre-production models could not be made from production tools and had to be hand-made.

NB This was the first time the production engineers were involved with the project.

Month 30

The production engineering department completed making of the tools and are now in the process of constructing the mincing machines.

Month 31

First few models completed. These were displayed at the exhibition.

Month 32

The production department continuing to make the machines and 30 off machines have been completed so far.

The exhibition performance of the machines were satisfactory.

Simultaneously, the production engineering department designing the tools to make these machines by production tools. Once the design of these tools is completed these will be made by an outside manufacturer.

Month 33

Some of the tools have been made and as a result full production started. However due to lack of availability of all the tools; the output not reached optimum levels yet.

The other tools should be made and delivered by Month 36.

Month 34 and 35

Production continuing making best use of the tools available. During this course a number of modifications resulted due to manufacturing difficulties.

Month 36

All the tools not yet delivered.

Month 37

Full production in progress, as all the tools are now available.

Observations

1 The Problems with the existing mincer were opinions of a number of individuals, these were not substantiated by any factual data.

2 The initial specification was very vague and was conveyed to the designer by the Technical Manager in a verbal manner and no written guidelines were prepared. In the initial design brief, cost, time or other design parameters were not specified and the designer was allowed to proceed with the project aimlessly. This resulted in confusion and conflict amongst the project members. This point was highlighted by the fact when the designer initially produced a wooden model and passed it to the Sales Director . The Sales Director failed to comment or provide any feedback information on this model, and the designer in the meantime assumed it must be satisfactory. As a result he continued with his work and constructed a working proto-type which was presented to the Sales Director . He rejected it as being completely unsatisfactory. This lack of communication caused a serious conflict between the design and the sales department and a wasted effort of some 9 months work.

The General Manager attempted to remedy the situation and initiated formal monthly meetings in order to improve communications and lay down detailed production specifications. At the first monthly meeting, in Month 10 a specification was devised, remarkably in the absence of the Sales Director. He was not even issued with a copy of the minutes of the meeting.

Even after this a great degree of uncertainty was still apparent as to the future demand of the type of machines under design and development. This point was highlighted in Month 11. When during the course of a meeting it was mentioned, "there was a feeling that the size 22 machine would become obsolete in the near future on the home market". However nobody knew precisely, what the situation was, nor was there any quantitative or qualitative data to substantiate this claim - it was purely based on feeling.

Similarly during the same meeting there was a doubt concerning the correct policy on size 12 machine and as a result it was decided to suspend any further work on this model and concentrate on the other two.

This degree of uncertainty of the details included the design brief were further excerbated when in Month 14 nobody knew of the exact safety requirements of the feed hole diameter for UK and overseas. Because during the course of the meeting it was felt that rumours exist that on the continent feedhole requirement was 40mm (1.57") as opposed to the proposed diameter of 2.125" on these range of new mincing machines. Again this information was based on rumours and not on any empirical evidence.

The weakness of the specification was further exploited when the Sales Director decided to involve himself formally in the project and attended a meeting in Month 13. During the course of the meeting he disputed a number of points laid down in the product specification. Also the fact the works cost of size 22 machine was estimated at £380. These points were discussed in the absence of the General Manager. However when he heard about these events he held another meeting only three days later to revise the specification. Only at this meeting a cost limit of £350 was imposed on the machine. Up to this point, for 13 months the designer was working on the project without any cost restrictions. Amazingly once again the Sales Director failed to attend this meeting.

The project was further thrown into confusion when the Managing Director decided to get involved in Month 17. During this month an argument developed between the Managing Director and the Sales Director. The Managing Director suggested that the company should only concentrate on size 32 machine and size 22 should be discontinued. However the Sales Director felt that both sizes, 22 and 32, were needed by the customer. This difference of opinion was based on personal preferences and feeling rather than on factual supportive evidence.

The design brief had several other drawbacks. Time limitations on the project were never imposed throughout the project initially it was agreed that production would commence in Month 22, but finally it did not start until Month 37.

There were no allowances made in the specification for servicing or maintenance of the machines.

3 Although the Chief Production Engineer was formally involved in the project from the Month 10, no consideration was given to the manufacturing processes or assembly techniques. The Chief Production Engineer's input was purely from the materials point of view. The Works Manager was formally present at the meeting in Month 17 when he was consulted regards machining of various parts for the prototype model.

4 The drawings were formally handed over to Production Engineering department in Month 29 when only one week was allowed to commence pre-production run. The newly appointed Manufacturing Manager was very critical about this. He said in his opinion handover stage is very important indeed and in this company insufficient time is allowed between issue of drawings to the production department and start of manufacturing operations. In this case only one week was allowed to

start pre-production run, hence the production engineering department has been unable to give sufficient attention to detail design from economic manufacturing point of view. He claimed that significant savings could be made in the manufacturing and assembly stage if the products were critically value analysed prior to its introduction to the shop-floor. In fact the data supports his argument as only one week was allowed to plan production operations whereas the design department had 28 months to work on the project.

It was Month 29 when the production engineers formally were involved in the project, prior to this they had no influence on the product design process.

5 A consultant industrial designer was half heartedly employed in Months 18 and 19, on this project and inadequate consideration was given to the ideas proposed by him.

6 The project was allowed to proceed regardless. By due to a number of reasons

- the company failed to identify precisely the market needs.
- the Technical Manager failed to demand a proper design brief from the sales department, as a result the designer was going in circles, which lead to frustration, confusion and poor performance.
- lack of strict management control regards time, cost and other parameters.
- the management, especially the Managing Director constantly interferred with the project at the detail design stage and continually imposed his own personal ideas onto the designer.

The management attempted to formalise the control of the project by having regular monthly meetings - this was not too successful, as not everybody related to the project attended these meetings. Even more significantly the minutes of the meetings were not widely circulated. For example, the minutes of the meeting were not circulated to the Sales Director or the Managing Director until Month 14. On the other hand although the Chief Production Engineer was present at these meetings, but the information never reached the production engineers or the estimators.

8 No formal standardisation procuedure existed during the course of the design process.

9 No information exists regards current stocks of parts, sizes of drills, reamers or milling cutters etc available in the stores. The designer therefore designed each individual part through his personal judgement rather than any formal guidelines.

10 Large number of modifications occured during the course of the project. For example, in Month 14 when the specification was revised no fewer than 20 items were modified.

11 The implementation of modification procedure is ineffective, resulting in

high proportion of scrap and rejection rate.

12 The monthly meetings were purely held for the management and insignificant input came from the designer or the production department. The senior management tended to dictate events and constantly interferred with the detail design process rather than guiding the designer. The decisions were imposed by command or instructions rather than suggestions. Also at these meetings, the functional design was continually discussed and insufficient attention was given to design for economic manufacture or assembly.

13 There was a tendency throughout the project to satisfy individuals, rather than giving adequate consideration to customer needs.

14 In Month 33, the designer claimed that insufficent time was given to develop his ideas. With more time he could have made significant improvements.

15 The degree of communication during the design stage between the design and production department was nil. On no occasion did the designer visit the production engineering department. In fact the designer claims he was fully conversant with the production techniques and as a result he instructs the production department how a component should be made.

16 There were a number of personality clashes at the centre of these were the designer and the Technical Manager . The designer was considered to be aggressive and extrovert whereas the Technical Manager was completely opposite in personality. The TM in general could not handle design projects adequately or the designer. As a result a new Engineering Manager was appointed. Although surprisingly the Technical Manager still retained his position but virtually without any authority.

17 The designer disliked instruction or orders and tended to 'do his own thing'. Any information such as minutes of the meetings or memos always ended up in the waste paper bin.

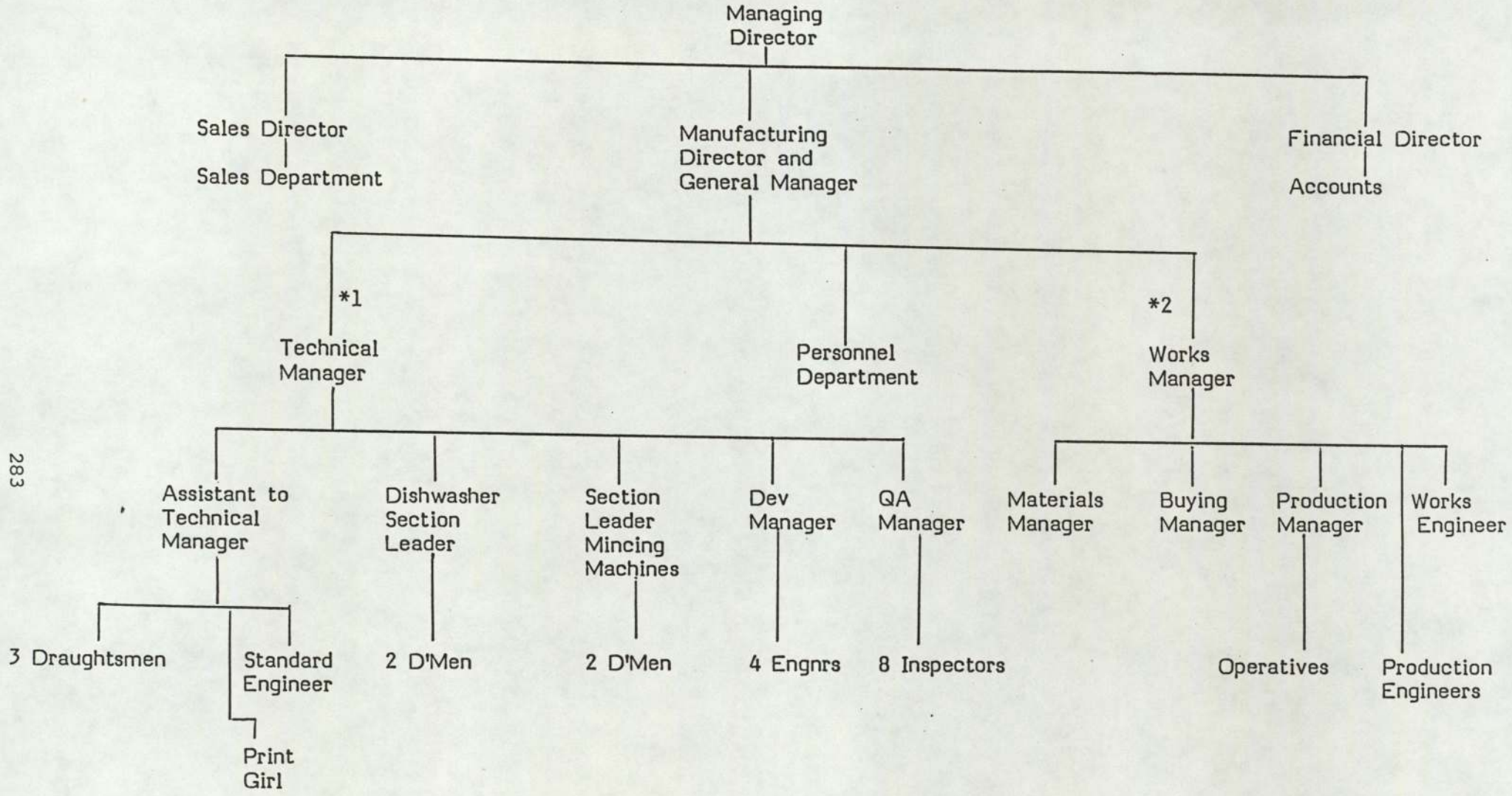
18 There is a large physical distance between the design and production departments - the designer claimed he did not know how many production engineers there were, as he never visited the department.

19 Both the designer and the Technical Manager were very conscious about their qualifications - they continually repeated throughout the project that they were chartered engineers so as a result they have the divine right to be correct on what ever they design. The TM was very critical about the calibre of the designers in the company, he said all of them are either up to GCE 'O' level or ONC standard except for three who were up to chartered engineers.

20 The designer was very status conscious and was always belittling production personnel regard incompetance and lack of talent and calibre. In fact the senior production claimed during the course of discussion that some of the 'young' production engineers are 'afraid' to approach the designer because of his attitude and aggressive manner. Hence the senior production engineer or the Chief Production Engineer usually liaises with the design department.

21 The company appears to be completely disorganised without any clearly defined policies, objectives regards new product development. Also it does not have any strict monitoring system for projects - the projects tend to 'drift along' without any pre-determined targets or aims.

22 In the design department there are no formal guidelines for the designers, for instance, on the size of paper to be used, the type of standard symbols to be denoted on the drawings etc.



*1 New Engineering Manager recruited in Month 20
*2 New Manufacturing Maniger recruited in Month 27

Figure Apx 6-1 **Simplified organisation chart of FPM Limited**

Appendix 7

MH LIMITED

MH Limited employing about 330 people, designs and manufactures materials handling equipment. The company, a subsidiary of a large American Group has a very strong marketing, servicing and vehicle hire network throughout Great Britain. To back up its marketing and servicing teams it has an excellent manufacturing base located in the Midlands region.

Product Specification

The product design process is initiated in one of the two ways.

1 The marketing department identifies an opportunity for a new product and constructs a broad outline of requirements, this is termed the 'commercial specification', which is then sent to the engineering department for a feasibility study.

2 The engineering department reviews existing products to identify cases of excessive costs, inadquate performance etc, this is followed by a feasibility study to establish the prospects for achieving improvements.

In both cases, a feasbility study is the mechanism by which a product specification is derived; the main purpose of the study is to determine whether a project is technically and economically sound. During the process of constructing the feasibility study, many formal and informal consultations take place. Requests for further informations from the marketing department are common and frequent approaches may be made to purchasing, costing and manufacturing. The study culminates with the presentation of several alternative design proposals together with the implications of each case. This report is circulated widely in the company before a meeting of representatives of all departments agrees on the final product specification.

The production department does not actively participate in the meeting but their services are often required to clarify production details. Engineering and marketing are the main contributors to the specification. The format of the specification is quite comprehensive and it includes details on the technical, financial and time aspects of the project.

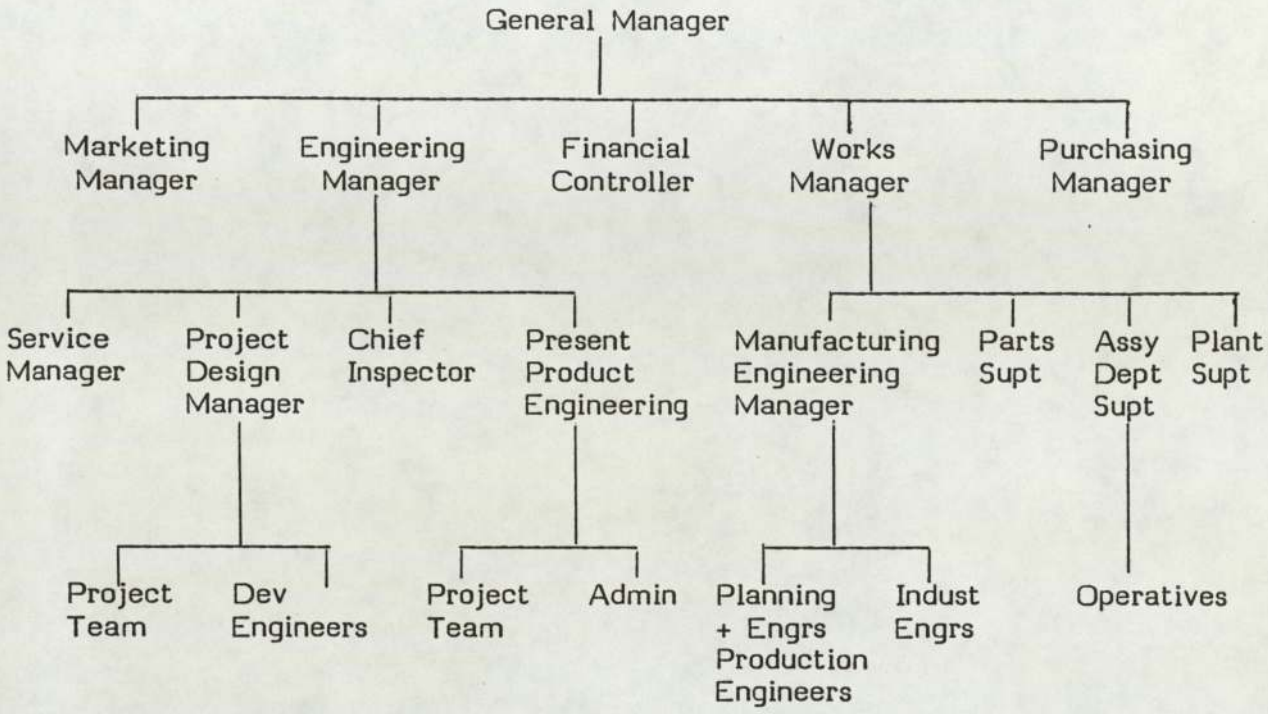


Figure Apx 7-1 Simplified Organisation Chart of MH Limited

Design and Development

Design work on the project commences and a prototype is built. At this stage extensive dialogue between marketing, design and production departments occur. This usually leads to numerous changes to the product within the agreed overall parameters laid down in the product specification. The prototype model usually undergoes exhaustive test procedures to check for durability and reliability etc.

Once the functional aspects are satisfied, the product undergoes value analysis. It is claimed that at this stage up to 25% savings are usually achieved, due to standardisation, elmination and improvements etc. The successful execution of the value analysis process exists due to of team work approach where representatives from all departments, ranging from top managemnt down to shop-floor level, are invited to contribute.

When optimum levels of savings are achieved without any loss in performance, detailed drawings are prepared by the engineering department.

Initial release of drawings to production

The engineering department hands over the detailed drawings to the production department to enable them to commence and design jigs and fixtures in readiness for production. During this stage frequent meetings, discussions and negotiations occur which frequently lead of amendments to drawings. At this stage tools are not made but are only designed.

Final release of drawings to production

Once all the details on the drawings and design of tools are agreed by all those concerned, the drawings are finally released to production. Manufacture of tools commences, and the production department designs production systems in readiness to manufacture the new product. Within about six-months after final release of drawings manufacturing operations commence. In parallel to this the marketing department prepares itself to initiate the introduction of the product on the market.

Observations

The complexity of the product demands thorough planning and a high degree of collaboration throughout the design process to minimise failure rate. The company as a whole has well balanced design, production and marketing expertise, together with a high calibre of project management. The management encourages good communications amongst its employees - both formally and informally. This has led to a successful product design and development record and given MH Limited a competitive edge over its main rivals.

Appendix 8

GR LIMITED

GR Limited was set-up in 1882 in the field of general electrical engineering but became specialist manufacturers of AC generators in 1978. The company became part of a major multi-national electrical group in 1973 and currently is engaged in the design and marketing of a comprehensive family of generators (both brushless and revolving armature). A recent addition to the product range is a series of low voltage DC motors for driving battery-powered vehicles and fork lift trucks.

The direct exports make up nearly half the company's production and are growing all the time. It is also involved in licensed manufacturing overseas.

The company employs about 420 people in a factory area of about 25,000m^2 within which a total manufacturing concept is maintained, thus reducing sub-contract to a minimum.

Recent investment has brought extensive use of some of the most modern of machinery methods, and there is a multi-stage progression tools press that is one of the largest of its type in the UK.

The three main market areas for the AC generators are industrial (comprising 60% of production), marine and telecommunications.

A first-class worldwide network of sales, after-sales and service facilities from carefully appointed agents and works based staff ensure attention to all details from inquiry through to installation.

Directors and sales staff travel extensively, supporting existing agents and customers in more than 50 countries and searching for new business.

Product Specification

The product design process is initiated in a number of ways.

1 Approximately 90% of the enquiries for new products comes from customers via sales representatives based in UK and overseas.

2 Customer approaches GR Limited directly by means of telephone or by letter. Sometimes customers give verbal requirements by telephone or on the other extreme, it can be very comprehensively prepared specifications. The latter is particularly true when consulting engineers are liaising with GR on behalf of a customer. Then the specification is usually precise and detailed.

3 If the electrical group as a whole (which GR Limited is part of) wins a major contract then any specific requirements for generators will be channeled to GR Limited.

4 When the company through its extensive contact with customer; identifies a specific need for a new product. Then the company after carrying out technical, enconomical and commercial appraisal will indulge in development of a new product.

In this case the design of a new regulator for generators is described;

Product Specification

Due to new technological break-through it was felt that a new electronically controlled regulator should be introduced. The management of the company assigned an Electronic Engineer to this project to carry out initial feasibility studies. The Electronic Engineer started on the project by carrying out technical and commercial surveys to see whether this type of device is possible to develop and if it is a commercially viable proposition. From time to time he was assisted by an accountant with the financial appraisal.

His initial findings were made available and discussed at a meeting known as 'Modifications Committee'. The following members of the organisation were represented at this meeting.

Managing Director
Technical Director
Design Manager
Chief Electrical Engineer
Production Engineering Manager
Works Manager
Electronic Engineer.

At this meeting the content of the design brief were agreed and all the technical, commercial and financial parameters were laid down. This later resulted in to a written product specification.

Note: In this company, a set of procedure exists for devising a design brief such as this. When all the members of the 'modification committee' are given a questionnaire listing 10 questions. The participants have to answer the questions relevant to their department. See Appendix for the copy of the questionnaire. The 'modification committee' which consists of all the above mentioned personnel with the exception of the Electronic Engineer. The main objectives of this committee is to discuss any problems relating to new product designs or any problems associated with the existing products.

Design and Development

The Electronic Engineer commenced design and development work on the new regulator - during this course frequent discussions took place between him, the Chief Electrical Engineer, the Production Engineering Manager and the Works Manager. During these informal dialogues details of the regulator as well as its manufacturability were debated. Production engineers also contributed extensively at this stage to assist the development of the first prototype.

When the prototypes was constructed, GR Limited approached a sister company in the group to carry out field tests on their operational generator. As a result

of these tests, a number of modifications, improvements to the product were carried out. After exhaustive tests, a new regulator was developed and detailed drawings prepared.

Production department was given the go-ahead to start tool design. Simultaneously the Proruction Engineers and Production Control department vetted the product from manufacturing point of view. This however did not result in further modification.

Post Design

This new regulator was presented at a sales conference when all the company's sales engineers were informed about the new product. Sales engineers were given a few samples which they could offer free to their regular customers for a trial period. In fact this was a way of promoting the new product as well as testing its applicability. Sales engineers were also given the relevant technical literature with the new regulator to distribute amongst its customers.

A few months later this regulator was formally made available to customers at an exhibition held in West Germany. This resulted in several enquiries leading to placement of firm orders.

In parallel to start of the marketing campaign, production systems were organised to manufacture these as and when required.

Observations

Company operates on an informal basis during the development of a new product but any major events are formally recorded. The projects are very carefully monitored throughout its duration. A number of modifications result during the development process which are carried out with the agreement of the members of the modification committee. GR Limited has a well laid out procedure to ensure faultless development process. Management promotes active involvement by all parties at the product specification stage and during the design and development process.

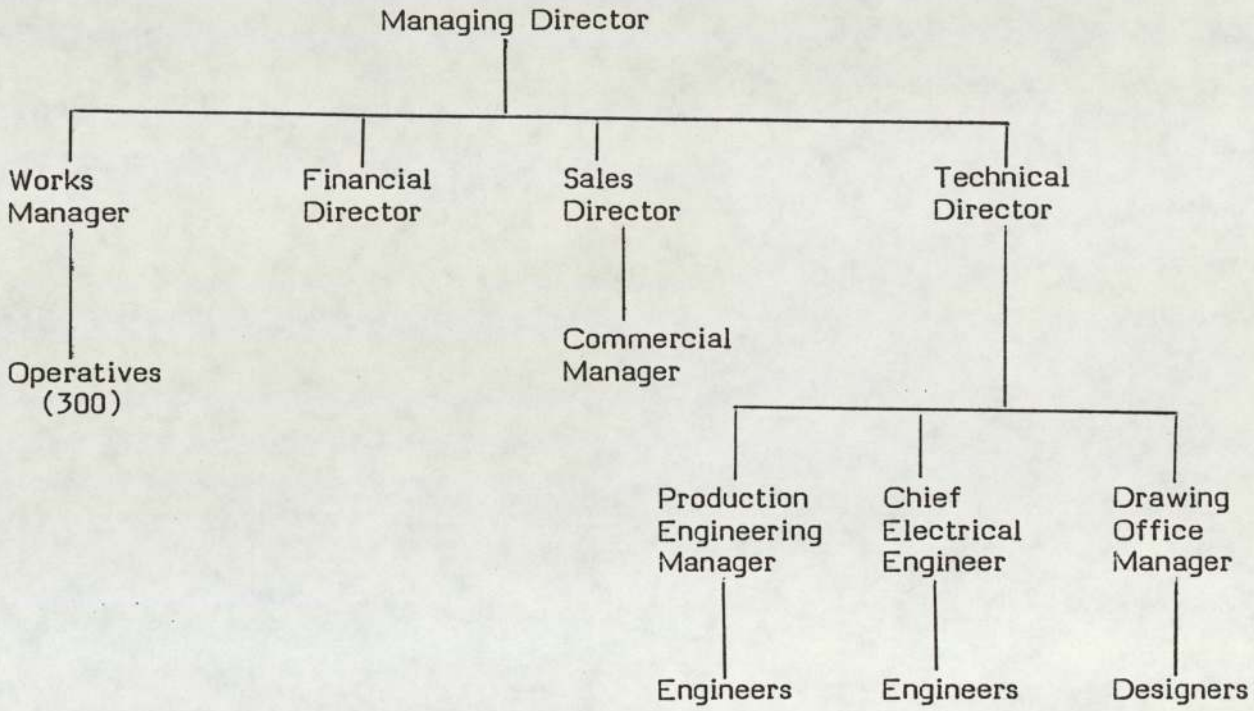


Figure Apx 8-1 **Simplified organisation chart GR Limited**

Ref No

GR LIMITED

REQUEST FOR MODIFICATION INTRODUCTION DATA

Modification No 0002

Classification

Equipment Code

INTRODUCE 1.12 80

This modification (details attached) was considered and agreed by the Mods Committee .....on.20.11.80.....

The following data is now required and is to be available at the Mods Meeting to be held on .....

* (delete as necessary)

MANUFACTURING

1. Cost difference on new production ....Fasteners 35p + 5p + £18.00...
2. Cost of Production scrap/salvage .....£770.00 studding .....
3. Cost of new/modified production tooling/test equipment...£250.00....
4. Availability of new and/or salvaged parts .....27.11.80.....
5. Estmited date for introduction into new production and unit serial numbers .....1.12.80.....
6. Number of new production units to be completed prior to introduction of modification .....NIL.....
7. Delay to production if immediate incorporation is mandatory .....1 WEEK.....
8. Lists of new/modified production tooling/test equipment .....

CINTI TAPES DE & NDE BRACKET JIGS & TRUNNION

COMMERCIAL

9. Price increase/decrease on new production units.....

10 Delay in new production delivery due to modification.....

Appendix 9

PIM LIMITED

PIM Limited established some thirty years ago as a family concern is engaged in the business of injection moulding plastic components for bathrooms and toilets. In 1974 the company was taken over by a well-known international group also involved in manufacturing a range of plastic products.

The company with a workforce of about 300 people is based in the West Midlands region and operates from a modern premises equipped with an up-to-date moulding facilities.

In the past PIM has enjoyed a reasonable degree of success in manufacure and supply of cisterns as well other plastic items. However the management felt that in order to maximise its plant utilization it needs to expand and perhaps diversify into other areas of plastics business. To fulfil their intentions the company entered into an agreement with a world's leading Chemical Company (CC) Limited. Up to this point CC only supplied raw materials to PIM Limited.

However in 1980 CC Limited successfully developed a new material known as 'Sylac' which is their opinion would be ideal to produce kitchen sinks with. Agreement between the two companies gave PIM priority over any other firm regards its use.

PIM's management responded immediately and assigned a Marketing Manager and a Project Engineer to investigate the viability of producing kitchen sinks from 'Sylac'. A bried survey was conducted in the UK and in other European countries with assistance of CC's sister company based in West Germany. This revealed that the trend across the continent for the last two years has been to manufacture kitchen sinks using polycarbonate material. The market research predicted that in the near future UK would follow their European counterparts.

In fact sufficient evidence existed to convince PIM's management that step in this direction would lead to future growth and prosperity for the organisation as a whole.

Product Specification

The Marketing Manager and Project Engineer were given the go ahead to carry out a detailed investigation into the feasibility of this project. Their study revealed that the following three options were available to the firm.

1 Manufacture sink unit in one piece from Polycarbonate.

2 Manufacture sink unit in one piece from Sylac.

3 Manufacture sink unit in small modular units from sylac and if necessary from Polucarbonate as well.

Option 1 - Manufacture sink unit in one piece from Polycarbonate

As mentioned earlier, the firms on the continent have been producing sinks this way for the last two years. However PIM's existing production facilities prevented then from following their competitors. Their current injection moulding machine had a maximum capacity of 850 tons locking force when the requirement to manufacture sink in one piece was 1200 tons locking force.

However within the group a 2000 tons locking force capacity machine existed but the Managing Director was reluctant to sub-contract the work outside due to adverse problems in the future such as delivery and liasion etc. Also the fact this was against their policy as the intention was to increase the utilisation of the existing production facilities. Another reason why the management was apprehensive to consider this option was the fact that Polycarbonate being a relatively cheaper material with poor properties - did not fit into their existing high quality image.

On these basis this option was considered to be unattractive.

Option 2 - Manufacture sink unit in one piece for 'sylac'

This option was same as Option 1 except the material changed from Polycarbonate to Sylac. Although the management considered this alternative to be ideal but due to similar problems, of production capacity, as in the first option, the company decided not to persue this further.

Option 3 - Manufacture sink in small modular units from Sylac and if necessary from Polycarbonate as well

The first two options, unjustifiably, required large investments in new injection moulding facilities. The Managing Director suggested the possibility of producing the sink in modular units. Technically this idea proved to be quite feasible as well as it would make use of the existing production facilities. Further investigations revealed this to be the most attractive proposition to the firm.

As a result based on this concept product specification was jointly devised by the Managing Director, Marketing department, Project Engineer, Production Manager and a representative from CC Limited.

(See attached diagram for illustration of the modular concept).

Design and Development

To optimise chances of success of this project, the Managing Director set up a 'product development team' consisting of the following members.

Marketing Manager	-	Chairman
Project Engineer	-	Technical expert
Production Manager	-	Production process expert
Industrial Engineering Manager	-	Concerned with maintenance and plant layout
Cost Accountant	-	Secretary to the team and an advisor of financial aspects
Quality Control Manager Buying Manager	-	Only involved as and when the Chairman felt their services were required.

An industrial Design consultant was engaged to propose alternative aesthetics of modular sink units within the broad guidelines laid down in the product specification. After numerous alternatives and frequent dialogues between the consultant and the members of the Venture Team, a final version was proposed. When this design was agreed by all those concerned, a detail design process was undertaken by the Technical department of the company. During this process formal meetings were held regularly every 2 or 3 weeks to discuss the progress of the project and highlight any foreseeable future problems. Minutes of the meetings were kept and widely circulated throughout the company. As well as these formal meetings there was a constant informal dialogue amongst the Venture Team members as and when required.

As a result, successful detail design was produced. The drawings were then formally passed to the tool designer and simultaneously Industrial Engineering Manager was extensively involved in the reorganisation of the shop-floor layout to introduce new product.

Trial production runs of the new product were carried out successfully. During the course of the trial run a materials technologist from CC Limited was present at PIM's premises to train Operators/Supervisors/Engineers in the materials aspect of the process.

Full production run started shortly thereafter. In parallel to this rigourous marketing campaign was initiated to introduce the product on the market.

Finally about two and a half years after the inception, the new product was formally launched on the market.

Observations

This case study typically illustrates the market analysis and subsequent successful product development process achieved through a team work approach. Also it shows the concept of 'product development team' which gave everybody a sense of involvement and achievement as well as minimising unsuccessful product development by prevention of problems rather than cure.

One significant point to note is the whole case study is the lack of involvement by the Works Director and the Technical Director in the project. This perhaps was deliberate by the Managing Director - about 18 months into the project both of them were given an early retirement - the organisation chart before and after the re-organisation shows that Production Manager and Project Engineer were both promoted to Works Manager and Technical Manager respectively. Also the Quality Control department was moved under the control of the Technical Manager.

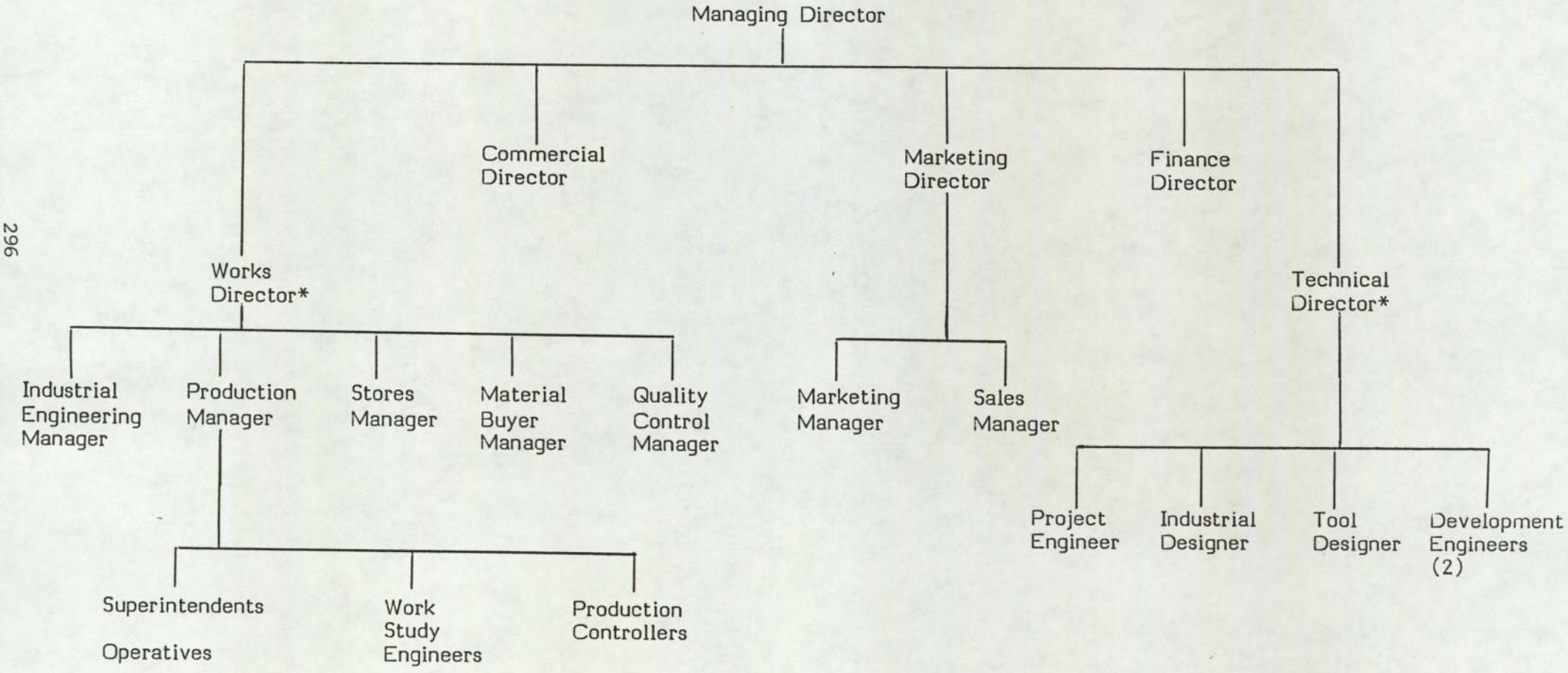


Figure Apx 9-1 - Simplified Organisation Chart for PIM Limited

* Not represented on the Board of Directors

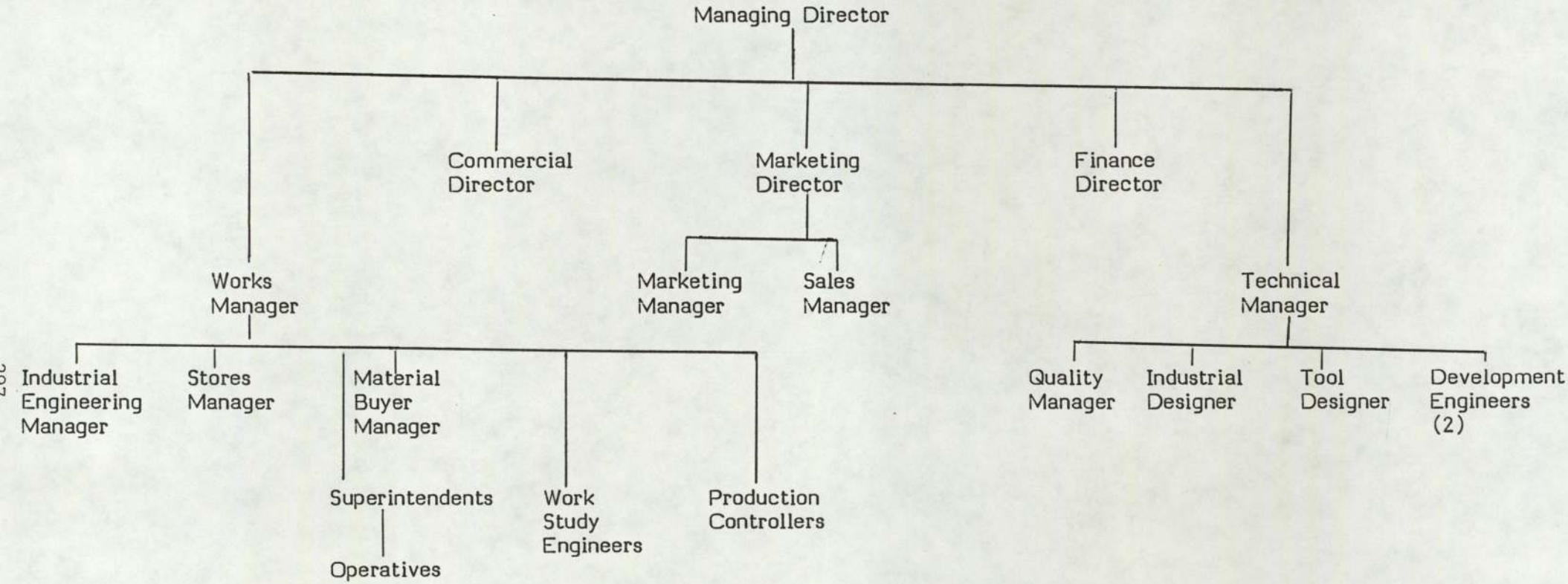


Figure Apx 9-2 - New Simplified Organisation Chart of PIM Limited

Appendix 10

PMT LIMITED

PMT Limited is based in the West Midlands region, with a workforce of about 250 and is engaged in the manufacture of plastic components mainly to customers specification. The company also makes standard products which are marketed through their sales department.

Product Specification

Normally the customers approach the company through the sales department regards their specific requirements. The sales department refers the enquiry to estimating and technical department for pricing and to resolve any foreseeable technical problems etc. If technically feasible, a quotation to the customer is submitted.

Based on the information in the quotation, if customer places a preliminary order, the design department commences design work. During this stage extensive dialogue takes place between the technical staff, the tool manager, and the production manager to identify and resolve any foreseeable problem areas.

This quite often leads to amendments of the existing quotation. The revised details are re-submitted to the customer. Based on the new information the customer usually places a firm order. This then is tranformed into a product specification.

Design and Development

Design department commences detail design work on the project with a continued assistance from the production manager and the tool manager, who between them, have some forty years of experience of manufacturing aspects in the plastics industry.

Majority of the problems are usually eliminated at the drawing board stage. (NOTE in fact in this type of industry it is imperative that problems are resolved at this stage, as the majority of the cost is due to tools.)

When tools are manufactured a trial production run is carried out and samples of the products submitted to customer for their approval and comments etc.

When customer is satisfied, a full-scale production run begins.

Observations

Liaison amongst members of design and production staff is satisfactory. There are a number of changes which take place at the drawing board stage but these are carried in consultation with production personnel. The company as a whole emphasises the importance of team work approach during the process of new product designs.

Appendix 11

GM LIMITED

GM Limited is a gearbox manufacturing company, employing around 200 people. The company produces 13 basic designs of gearbox, within these there are many choices of ratios, mounting options, shaft sizes and horsepower capacities. This enables a comprehensive range of transmission products. The company also to collaborate with customers to produce their specific requirements. The following points are considered to be very important.

1 Initial contact with customer to examine parameters and objectives.
2 Initial outline design concept and budget costing based as far as possible on existing products.
3 Communication with customers to approve and/or modify earlier proposals.

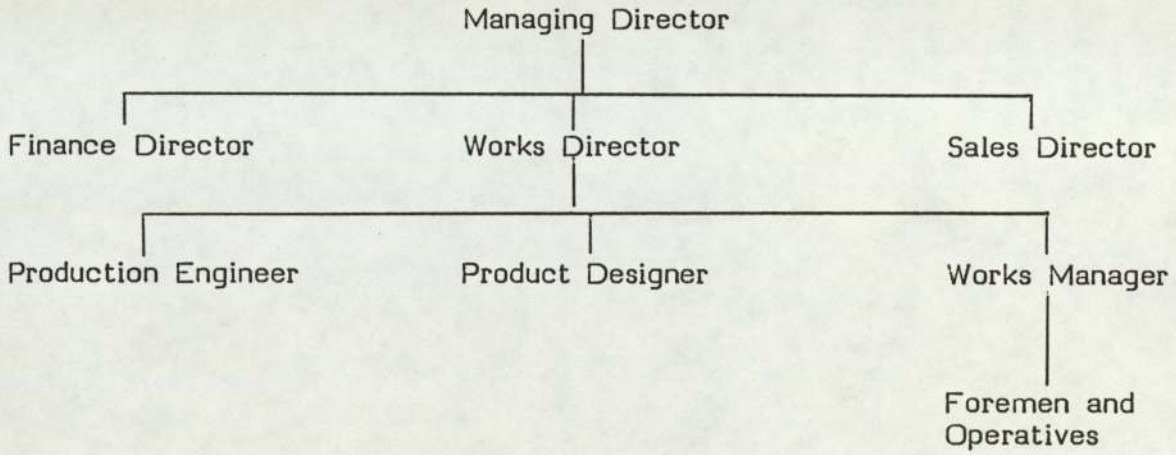


Figure Apx 11-1
Simplified organisation chart of GM Limited

The company has a questionnaire for prospective customers. This provides the maximum amount of information about the customers requirements.

The consequent steps from this until production commences are:-

1 Meeting with customers to examine parameters and objectives.
2 Initial outline design concept and budget costing.
3 Meeting to either accept or modify concept.
4 Tempororary tooling/wooden pattern equipment laid down for production of samples.
5 Production and prove-out of samples in field.
6 Modification and final costing.
7 Full production tooling and production commences.

Design processes of a typical new product is illustrated by the following example.

DESIGN OF A GEARBOX FOR HEDGE TRIMMING TRACTOR

Product Specification

GM Limited were approached by a customer (Hedge Trimmer Limited) regarding the possible design and production of a new gearbox to suit their requirements which were to enable a hedge-trimming apparatus to be utilised on an existing tractor.

Hedge Trimmer Limited were asked by GM for their proposed specification, which was handed over.

The Chief Designer at GM, inspected the customer's specification and re-designed some of the component so that it was economical and feasible for manufacture.

These outline assembly drawings were then returned to the customer for approval. At this stage, three options were available to Hedge-Trimmer Limited.

These were:-

1 A conversion of an existing gearbox.
2 A partial conversion of an existing gearbox using a conversion kit.
3 The design and manufacture of a completely new gearbox.

Estimated costs of each option along with drawings and other details were prepared and sent to Hedge-Trimmer Limited.

Once Hedge-Trimmer Limited were satisfied with both the design and the price, they chose the third option - a completely new gearbox design.

The customer requested that two modifications should be made to the design:

1 The company wanted their own name added to the flange of the gearbox.
2 A plug to be added to the lid.

Design and Development

A detailed drawing of the gearbox was prepared by the design office and sent to production so that tools can be made. After th drawing had been inspected by the chief production engineer, a modification was suggested on a component known as trunnion. A radius of 0.18" had been drawn at the base of a hole of 0.75" diameter and depth 0.38" and it was suggested that this radius was to be replaced by a chamfer.

The chief design engineer agreed to this modification and the appropriate drawings were modified. The changes were made before any of the drawings left either the Production Engineers or the Design Engineers Offices, and therefore no amendment had to be noted on the drawing itself. The Chief Production Engineer also advised the chief design engineer to make a modification to the rear face of the gearbox mounting flange. The lower half of the flange had the rear face at a slightly higher level than that of the upper half and it was advised that these faces be made level so that machining could be carried out in one operations.

The chief design engineer the produced a schedule of materials. Copies of this schedule were sent to various departments throughout the organisation. These departments were:

Purchasing Department - for ordering materials
Stores Department - for storage of materials
Production (Shop Floor) Works Manager - 3 copies of drawings issued to shopfloor
Sales Department - for information purposes only.

After the first prototypes had been produced, testing for 6-7 hours occurred in order to ensure that the lid and the plug within it did not show any signs of leak.

It was found that only one new tool was required from outside - a broaching tool - and this was paid for by the customer.

During developing and testing it was found that no modifications were necessary.

The first three gearboxes produced had to be scrapped as the required chamfer was incorrect due to the fact that it was unclearly specified on the drawing - later clarified.

Manufacturing Stage

During the progress of the gearbox towards production, a problem concerning the mounting flange began to appear during assembly. It was found that the top bore did not match up with the drilled holes in the body in 2 gear-boxes.

The problem was first spotted by the inspector on the shop-floor and the chief designer was asked to investigate and modify the design. The problem was referred to the chief production engineer who suggested that there was a need to modify the design of the jig so that it was located from the body holes rather than from the outside of the body of the casting.

(It is interesting to note that the problem of this location did not occur until the inspection stage; it was overlooked by both the Chief Design Engineer and

the Chief Production Engineer).

The modification did not involve any alterations to the drawings, because the fault lied in the jig which was duly corrected.

No other modifications were necessary apart from this.

Observations

The customers requirements were considered to be very important during the course of the product specification compilation. This was further enhanced by the use of a questionnaire and hence identifying all the key components of the specification.

At each stage of the design, the customer was involved, for instance when approving modifications. The key stages involved in the design project were as follows:

Stage 1 Customer Requirements determined by Customers Orders.
Stage 2 Customers Requirements changed to Product Specification.
Stage 3 Design and development and Production Drawings prepared.
Stage 4 Handover of drawings from Design to Production and Tooling.
Stage 5 Manufacturing of parts, testing, inspection.

The customer, the sales department, the estimating department and the production management all had little or no involvement in the project although they were all aware of its existence. The production engineering department, however, had extensive involvement in the design process and this was a major factor in the success of the project.

In this project example, there was a satisfactory working relationship between the design and production departments which lead to success. This good relationship, which is vital to the future of the project, was due to a number of factors. The two departments existed closely to each other; worked together as a team, and showed good personal relationships between the two departments. Perhaps the most important of all, however, was that the communications systems between the two was very good, which contributed towards them working as a team.

Appendix 12

AF LIMITED

Company AF with a workforce of about 200, manufactures ranges of standard and special architectural ironmongery such as doors, windows, handles etc. As well as manufacturing products, it also provides a design and advisory service mainly for commercial properties.

The business has been owned by the same family, spreading over some eight generations, since 1670. It has been run by a Managing Director for the last six years. The company's organisational structure is split into different sections as shown by Figure Apx 12-1.

Technical department

This department performs the design and development function for all the copany products. It is headed by the Technical Manager, who has been with the company for some 20 years and has only 5 years prior to his retirement. The Technical department is further split into two sections; design and development and projects. Design section carries out all the preliminary design and development work on new products and project teams take over the work thereafter and do the remaining detail design work.

Manufacturing department

This function is headed by the Works Manager, who controls the Manufacturing, Transport, Production Engineering as well as being Company's Personnel Specialist. His responsibilities are further delegated to the Chief Production Engineer - who deals with the production engineering aspect of new products, as well as organising production systems. The Production Superintendent deals with the day-to-day running of the manufacturing operations.

Product Specification

The company does not have a single standardised procedure for evaluating ideas and drawing-up specifications, although in practice, two methods are found to predominate. The first method applies to enquiries for special products received by the sales department. Observations show that up to 70% of these enquiries are declined by the sales personnel on the grounds of unsuitability. No formal guidelines exist - each decision is based on the judgement of the sales engineer and only rarely is reference made to any other section of the company. The remaining enquiries are passed to the design and estimating departments where quotations are prepared. Following acceptance of a quotation by a customer, the design department finalises the product specification and commences design work.

The second method operates when a specification is being devised for a new standard product. The procedure for this is outlined as below:

At a board meeting it was decided to commence studies of a new window design to overcome the inadequacies of the existing design. This existing design had earned the customers disapproval due to variations in quality and fitting

difficulties.

The Technical Manager was put in charge of proposing different possible ideas for a replacement of an existing vertical pivoted window. He collaborated with some of the designers and three new ideas were put forward, with the appropriate drawings for each.

A meeting was held to evaluate these three alternatives.

Present:

Managing Director
Technical Manager
Buying Manager
Chief Production Engineer
Works Manager
Estimating Manager
Production Superintendent

At this meeting one of the proposals was ruled out as unsatisfactory. Further information was requested on the other two alternatives. Design and Estimating department in collaboration with each other carried out preliminary technical and financial comparisons between these two windows.

Another meeting was held attended by the same members as on the last meeting - one of the proposals was accepted and the other was rejected. Also during this meeting a product specification was agreed on along the lines already suggested by the design department, this new window being labelled as 'Mark IV'. It was agreed all the necessory design work will be complete by the end of Month 2.

The design department was given the go ahead to commence detailed work on this model.

Design and Development

Basically on this window there are the following major parts: locking mechanism, cleat and rubber seal for the glass pane, pivot, frame bars and handle.

During the design and development process, events relating to these parts is described below.

Month 1

The Technical manager and the two designers started work on this project.

Pivot: The design of the pivot is quite complex and the designer was uncertain of the best way to design and therefore he provided verbal instructions and sketches to the production department to develop his ideas into practical propositions. As the production department performed each manufacturing step the designer analysed the situation and gave further instructions. In parallel to this the designer produced the relevant drawings.

Frame bars A suitable configuration of the frame bars has been agreed between the design and production departments. The drawings of these has been sent to the suppliers so that these can be extruded. However other dimensions and the position of items such as handle, locking mechanism and the pivot on the frame bars only preliminary agreed upon - these are likely to change as other parts become available.

Cleat The cleat serves the functions of joining together the horizontal and vertical frame bars of the window at the corners. This is achieved by inserting the cleat into the hollow section of the adjoining frame bars and secured into position by crimping process.

The design of the cleat produced by trial and error method, the desginers like for the pivot, issued verbal instructions to production and developed his ideas. This was machined from a solid piece.

Later on in the month, a meeting was held to discuss the Mark IV window and other design and production problems. Those present included; Production Director, Chief Production Engineer, Production Superintendent, Designer and Foreman.

NB The Works Manager has been promoted to the position of the Production Director.

Month 2 - Week 1

A rig has been designed and made in the development workshop so that the completed development window frame could be tested for air and water leaks.

The initial design of the window was completed and the window positioned into the test rig.

Pivot: When the window was fitted into the rig - it became obvious that the pivot needed to be modified to improve its operation.

Cleat: The use of the cleat left a gap at the corners adjoining horizontal and vertical frame bars. The gap proved to be a water leak problem and allowed water to enter the frame.

Frame bar: Due to one length of the bar being badly dimensioned, it was incorrectly cut. This mistake has since been corrected, and the blame has mainly been attributed to unclear dimensions on the drawing.

Handle: It has been found that the hole in the handle was 8mm square, whereas the spindle which fits in it was 7mm square. It has been discovered from testing that aluminium bush in the handle will have to be changed to a nylon one due to excessive wear.

Month 2 - Week 2

Rubber Seal: The sealing system for the window seemed to be ineffective when tested for resistance to wind and water pressure. The seal failed at 20 psi. whereas it should have been able to withstand 30 psi, so at the moment the design department is considering how to overcome this problem. The outside supplier of the seal is helping the design team to

redesign the seal.

The window design has also been tested for wind speed; the target was that it should withstand 63 mph and this has been achieved satisfactorily.

Pivot: The nylon slides to operate the pivot were in the course of modification; 3 or 4 different ideas are in the process of evaluation but final choice had not been made at this stage.

Cleat: Various designs (and drawings of these) had been made for the cleat but again no final decision had yet been made.

Handle: The change in material for the bush to eliminate wear problem has been accomplished.

Month 2 - Week 3

The seal will be delivered in about two weeks by the outside supplier and when this happens all tests will be repeated.

Month 2 - Week 4

The cleat has been modified so that the make-up piece has been eliminated and it was now of one piece construction.

The frame bar has been modified so that it takes the place of the make-up piece used before.

Month 3 - Week 1 and 2

The new seal has now arrived but it did not fit the window frame satisfactorily so the frame was modified to suit it. The frame bars were being machined in production department to accept the new seal. There had been no communications between the design and production departments as to the reason why production were machining the bars.

There has been little progress over the last 3 weeks, although it was initially thought and agreed that all the design work and testing would be complete by the end of Month 2. So the project was already behind schedule.

The Chief Production Engineer revealed that no tooling would be desgined and ordered before the design work is compelted. The higher management are not prepared to take the risk due to the unhappy experiences with previous projects when a large amount of tooling had to be scrapped and replaced before production could begin.

Month 3 - Week 3

The company still experiencing some problems with the seal; it appears to be too big and does not fit properly and therefore cannot pass the necessary tests. Further meetings between the design department and the outside supplier of the seal are to be held.

Previous pivot design and locking method completely unsatisfactory and as a result redesign of these two was required.

Month 3 - Week 4

There are still some problems concerning the seal as it is still unable to pass the water penetration test.

The handle on the prototype window was both loose and sloppy and an apprentice has been given instructions to redesign it. The production department was not been consulted regarding the redeign.

Month 4 - Week 1

The progress of the Mark IV window was discussed with the PS - he did not know of the detailed progress - all he knew was that it was being tested. He could foresee a problem concerning the painting of the frame. This is done outside as there are no suitable facilities available within the company; there could be problems with transport delays and damage or loss in transit. The painting is also carried out before assembly which could also lead to possible damage of parts.

The seal is being redesigned yet again.

Month 4 - Week 2

The board within the Ministry through which the design has to undergo has been to visit AF Limited and to look at the new window as well as its progress. They appeared generally satisfied, but pointed out that some corners on the handle were somewhat sharp.

The handle has duly been modified to overcome this problem.

Month 4 - Week 2 and 3

The section of the outer frame bar has been changed again but the production department (who mentioned the change) did not know the reason for it.

There was also confusion concerning the position of the pivot on the outer frame bar. According to a verbal information from the Technical Manager to the Chief Production Engineer the position is at the centre of the bar, but the drawings sent to the production department show it off-centre. However the designers say that the Technical Manager instructed them that it was to be off-centre. As a result no work is progressing in this area until the Technical Manager returns from holidays, the following week.

Month 5 - Week 1

The Technical Manager has explained that the pivot position should be off-centre so that the inner frame can swing through almost 360 degrees without fouling the outer frame.

Mechanical endurance tests are being carried out on both the pivot and the handle. The company assumes 700 operations per year for 30 years but when a safety factor is included the total rises to 50,000 operations, which is the number this test involved. Every 5000 operations the window was dismantled and inspected for wear or any other problems. The Technical Manager said if the tests are successful, the go-ahead for manufacture would be given.

The design department informed production department to build 6 or 7 complete windows which are to be used for demonstration and advertising purposes.

Month 5 - Week 2

The endurance test have been completed successfully and the report was compiled. However before the tests could be completed, the nylon pieces in the pivot were modified and the body of the pivot also necessitated changes, because too much force was required to open the window during the tests. Although the Chief Production Engineer believes that excessive wear was to blame. The production department was not consulted during the change.

Month 6

The handle was redesigned; originally it was to be extruded but now it is to be shaped by a machining process.

The locking mechanism failed during tests after 20,000 operations. It was found that the spring had broken; a steel spring replaced the existing brass one to overcome the problem.

The go-ahead was given by the design to production to commence making jigs and fixtures. The company received orders for 30 new windows with delivery to be made in Month 8.

Month 7

A tufnol friction pad has been added between the two halves of the pivot to reduce excessive wear due to friction.

The outside supplier of the seal has delivered two more new designs - both of which are unsuitable, so yet another new design was due to arrive soon.

Month 8

The revised seal found to be satisfactory but water tests not yet carried out.

There was a problem with the pivot because the inner window frame was not at 90 degrees to it. This was thought to be because the proto-type pivot was sand cast, not pressure die cast as the production versions will be. This problem will therefore be overcome once production begins.

Month 9

The new window is progressing satisfactory through its production process.

The new design of seal has been successfully water tested at 35 psi.

Month 10

The company are having teething problems with the production process, the Technical Manager claims that this is due to an incompetent and incapable production department suggesting a lack of skill and limited ability.

The jigs and fixtures for assembly have been made but the operators are

unfamiliar with their operation and this is causing problems.

During initial production, various parts have been shown to have shortcomings not noticed before. For example, there are still some problems concerning the rubber seal for the window, even though it has passed all the necessary tests. It has proved difficult to fit it correctly at the corners of the windows because it is almost impossible to cut it to the required dimension by a simple method. The cut needs to be stepped rather than straight so that it matches up at the corners of the window and this is causing the problem. The seal also becomes adrift from its correct position sometimes when the window is opened and closed. The problems are causing concern as the solutions required do not appear to be obvious ones.

The frame bars are not up to the required standards and there are problems with the corner joints not meeting correctly. This in turn is making the locking mechanism ineffective. However the outside supplier of the frame bars have assured the company that future deliveries will be of better quality.

The design of the pivot also has some faults which are making the window very stiff to operate. In addition to this, when the window is in the open position, the weight which is now acting directly on to the pivot makes the window even more difficult to close. The design of the pivot therefore needs to overcome these problems.

The Production Superintendent pointed out that the time taken to crimp the corner of the window was four times longer than that for an existing window of a similar type. He blamed this on the fact that the Cleat consisted of two separate pieces (the cleat and the make-up piece) and it was very difficult for the fitter to hold these two pieces and the two adjacent bars together in their correct positions during the crimping process. He said that in his opinion, there should only be three parts involved at the very most and that had more thought been given to the situation at the design stage, the problem would not have occured at all. He considers that the only answer to the present problem is to change the design and/or the method of manufacture of the parts and the materials used. Ideally the cleat and the make-up piece should be combined into one piece design.

For the project itself, although the process layout has been completed for the machined parts, it has not yet been done for the assembly stage and the fitters have not yet received an assembly drawing even though manufacture has started.

The production capacity for the manufacture of the new design is insufficient and the company is having to invest in new tooling for use on the existing machines so that the windows can be manufactured economically.

The Production Director and the Superintendent both agreed that the problems experienced so far could have been largely overcome with much better communication between the design and production departments. Neither of them had any idea why the parts had been designed the way they had and not any time had the production department been consulted regarding the design process. They added that the degree of communication in either direction was virtually nil.

Suggestions were made concerning the design department making a video film describing each of the various parts and outling their assembly which would then be passed to the production department. The production department considered

this to be a promising and helpful idea but didn't think it was feasible due to the expense, because the company were not in the best of health financially at the present time.

At the present time the company is working on a short-time basis of only 4 days a week. The designer of the Mark IV window project accepted voluntary redundancy and left the company.

Month 11

The BSI examiner had visited the company to see the window and unfortunately the locking mechanism had jammed whilst he was operating it. The window has been taken away to the BSI headquarters for further tests and AF Limited have been forbidden from selling any windows until tests are passed.

The other designer now working on the project explained that the problem with the cleat could be overcome if it were a one-piece and manufactured by pressure die casting process. The management are reluctant to give go-ahead because it involves purchase of a die costing about £5000. The two-piece cleat currently used is produced by extrusion process which does not involve any capital expenditure. He agreed that this would be expensive but it would be beneficial as a long-term investment, but the Managing Director doesn't see it this way.

He considered also that the introduction of the video film idea would improve communications between the departments considerably.

A discussion with the Technical Manager exposed a totally different opinion of the problems and their causes. He stated that in his opinion, most of the problems were entirely due to the incompetence of the production department. He thought that moves to improve the communication between departments would be a complete waste of time. He added that production department's job is to manufacture and assemble the product as instructed by the design department.

Month 12

A meeting held by the Board of Directors to solve the problems concerning Mark IV Window Project.

The main outcome of the meeting was that the organisational structure of the company was altered, in order to encourage greater co-operation between the design and production departments.

See Figure Apx 12-2 for new structure:-

There are still some problems with the window. AF Limited have used more of the new design themselves as part of the new offices and there are draughts and whistling noises. The faults are thought to be caused by the seal which may have to be modified again.

The standards of the incoming batches of the extruded frame bars are still not up to the required standards and recently a large batch has had to be rejected.

Month 13

The Production Superintendent said that the organisational changes has not brought any progress at all and there have been no positive moves to sort out the problems as far as the Mark IV Window Project was concerned.

He added that sales were going ahead even though all the problems are not yet ironed out and that the decision to do this had been taken by higher management. He was not in favour of this idea personally and would like to see all the problems cleared before delivery as opposed to possible customer complaints.

Month 14

No further developments.

Month 15

The Production Director revealed that the re-organisation of the company's structure had resulted in an improvement in communication between the design and production departments, and now both the Chief Production Engineer and the Production Superintendent were actively involved in design. The Technical Manager was not too happy about this but he accepted the situation.

The company have reduced the price of the Mark IV window and as a result of this, orders are increasing and the future looks somewhat brighter.

Month 16

The cleat still manufactured in two pieces; the design department suggested it should be glued together to ease problems during assembly. The production department, however are not keen on this idea.

Pivot was also causing problems, now the locking pin inside the body was shearing off prematurely.

Production department attempted to increase efficiency by improving manufacturing techniques. For example, holes and slots in the framebars are now punched out as opposed to drilling or milling them.

The Production Director said design/production relationships have not improved as he had anticipated due to the organisational changes. The Technical Manager still reluctant to co-operate fully.

Month 17

The handle design has not been finalised yet; the design department unable to arrive at the suitable shape. This problem has been contracted out to a consultant architect - who will design the aesthetic aspect and the design department will deal with the functional part of the handle. The Production Director and the Sales Director to initiate Product development committee meeting - whose function will be to value analyse existing range of products.

Months 18 to 20

The project still progressing very slowly.

The company as a whole still declining.

Month 21

The Managing Director resigned to take an early retirement.

Month 22

New Managing Director appointed by the company.

Month 23

A number of changes introduced by the new Managing Director; the organisational structure changed - see Figure Apx 12-3.

The total workforce has been reduced by eighteen personnel. Six shop-floor workers accepted voluntary redundancy. However twelve members of staff were dismissed including the Technical Manager and the Buying Manager. Although the Technical Manager has been re-employed as a independent consultant to the company.

Two additional sales representatives recruited.

The Production Superintendent promoted to Production Manager's position.

The Section Leader from a project team promoted to the post of the Technical Manager.

Months 24 - 27

Company's performance continually improving.

Month 28

In the last 6 months, since the appointment of a new Managing Director, the company has made a remarkable progress; some of the improvements or changes made are as follows:-

- In the last 6 months the company has made £60,000 profit - whereas before its loss making was well into six figures.
- The style of management has changed from defensive to that of positive participative management
- Increased emphasis on advertising has been placed for example, the company now advertises in newspapers and journals etc.

- Previously the highest turnover of the company was between £3-4 million per annum, but the new Managing Director aiming for £7 million turnover within a year.
- The company now working 7 days a week whereas before production was down to 4 days a week.
- Introduced monthly management meetings outside the company.
- Given the workers a 5% rise in wages and also improved the bonus scheme as well, whereas before last year there were no increases in wages.
- Successfully applied for a government grant to improve the design of the product by employing a design consultant for seven days.
- Also successfully called in a government sponsored consultant to give 15 days free consultancy service on the production systems.
- Attempting to diversify product range from its present commercial stance to domestic markets as well.
- Previously, usually 70% of the enquiries were declined on the ground of incompatibility with the company's existing product range. Now this policy has been changed and all enquiries are quoted for.
- Previous Managing Director was reluctant to buy capital equipment, but the new Managing Director has already invested extensively in new tools and purchase of new machines is likely in the near future to improve manufacturing facilities and techniques.
- The design department was previously separated into two district areas namely Project Teams and Design, as well as situated in different locations in the factory. Now these two coglomerated into one office.
- On the Mark IV window project numerous complaints received from the customers concerning pivot and seal. As a result of continued harrassment and the design department proving unable to come up with a suitable pivot design - the existing pivot idea completely abandoned. A complete new pivot has been bought from another window manufacturing company and this is to be used on the Mark IV window.

Observations

1 Design commenced with pre-planned targets for completion of various stages . Product specification and initial design carried out accordingly to plan but a series of problems occurred after tests. Major design changes resulted and design work was allowed to proceed without any timetable until completion. All the design and development was to be completed by Month 2, but observations show it was in Month 9 when production commenced even then haphazardly.

2 Design department rarely consulted production during the course of design process. Flow of information was essentially in one direction in the form of a 'command' by design to production as to when to proceed with certain items such as tooling. There was no feed-back of information from production to design - or vice-versa. On a few occasions production attempted to highlight foreseeable difficulties but

these were dismissed as irrelevant or insignificant by design department.

3 No formal channels of communication existed; there appears to be considerable uncertainities amongst production personnel regarding future demand and production capacity required for the new product.

4 No meetings were held during the course of the product design cycle to discuss the possible causes of delay or problems. Early in the project, a series of weekly meetings were initiated by the production director between design and production departments to identify problems. Only three meetings were held before the idea was abandoned due to lack of interest.

5 No consultation or discussion took place on any occasion to determine whether one design might be more convenient or less expensive to produce than another. Assembly time factors were not considered during the design process.

6 In month 9 manufacture started but production found some difficulties during assembly. However, it failed to generate sufficient interest in the design department to devise a course of action to alleviate these problems.

7 During month 12 the Managing Director re-organised the company structure (see Figure Apx 12-2) to improve the involvement of production in design matters. However this was completely unsuccessful, in fact as a result of this more problems were created.

9 No standardisation of components practiced in new designs. No attempt was made to use parts from previous designs already in production.

10 During the course of the project a number of personality clashes were apparent; at the centre of the whole issue was the Technical Manager who seemed to dominate the design process completely. The data indicates the Production Director and the Managing Director were powerless against him and the Technical Manager appeared to 'do his own thing'.

11 The extent of production involvement during the design stage was virtually nil and they only got involved at the handover of the drawings stage. This resulted in frequent changes to the product design which subsequently lead to ill-feelings amongst the members of the two departments.

12 The Buying Manager during the course of the project commented that the product was designed to suit the customer not the production systems in the company. The data shows that even the customers needs were inadequately considered.

13 The management claims to believe in both formal and informal system of liaison - but it appears which ever type of system the company operates - it is ineffective.

14 The design department enjoys a significantly higher status than production engineers as a result there is an insufficient emphasis on design for economic manufacture in the company.

15 The company has inadequate expertise concerning industrial design and methods engineering. These are highlighted by the fact, that eventually, the handle had to be contracted out to a consultant and the company were unable to place sufficient emphasis on 'design for assembly'. In the production engineering department sufficient knowledge exists on machining techniques but huge gaps are apparent on the assembly aspects.

16 When devising product specification analysis shows decisions are taken without reference to quantitative marketing or production data. Usually a project is, initiated by the Technical Manager , who apparently, derives his 'feel for the market' from participation in the activities of a trade association. When specifications are devised, the sales department is not represented at the initial meeting. Perhaps even more significantly, when the specification was prepared, the company was operating without a Sales Manager.

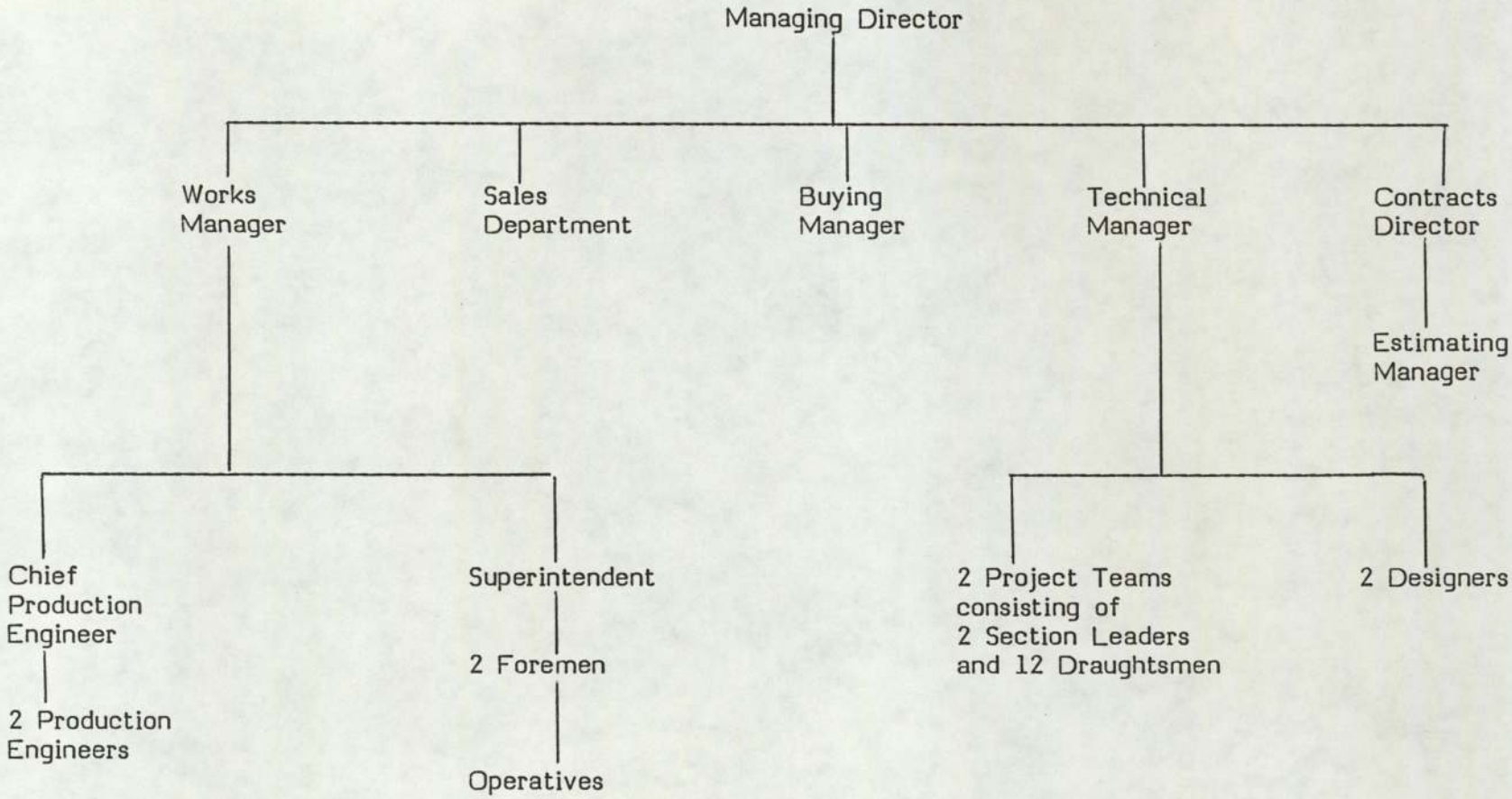


Figure Apx 12-1 Simplified organisation chart of AF Limited

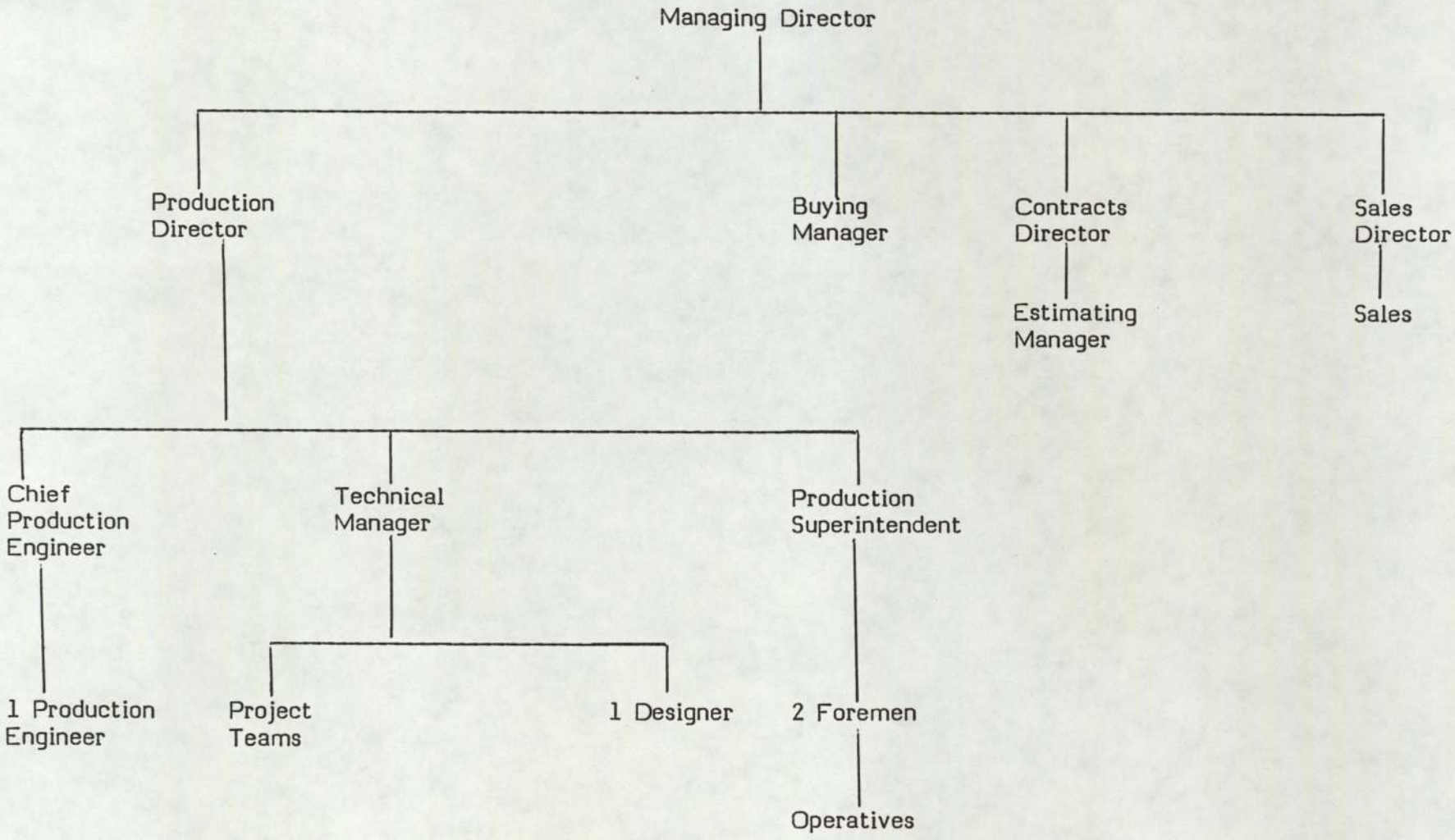


Figure Apx 12-2 - New simplified organisation chart of AF Limited

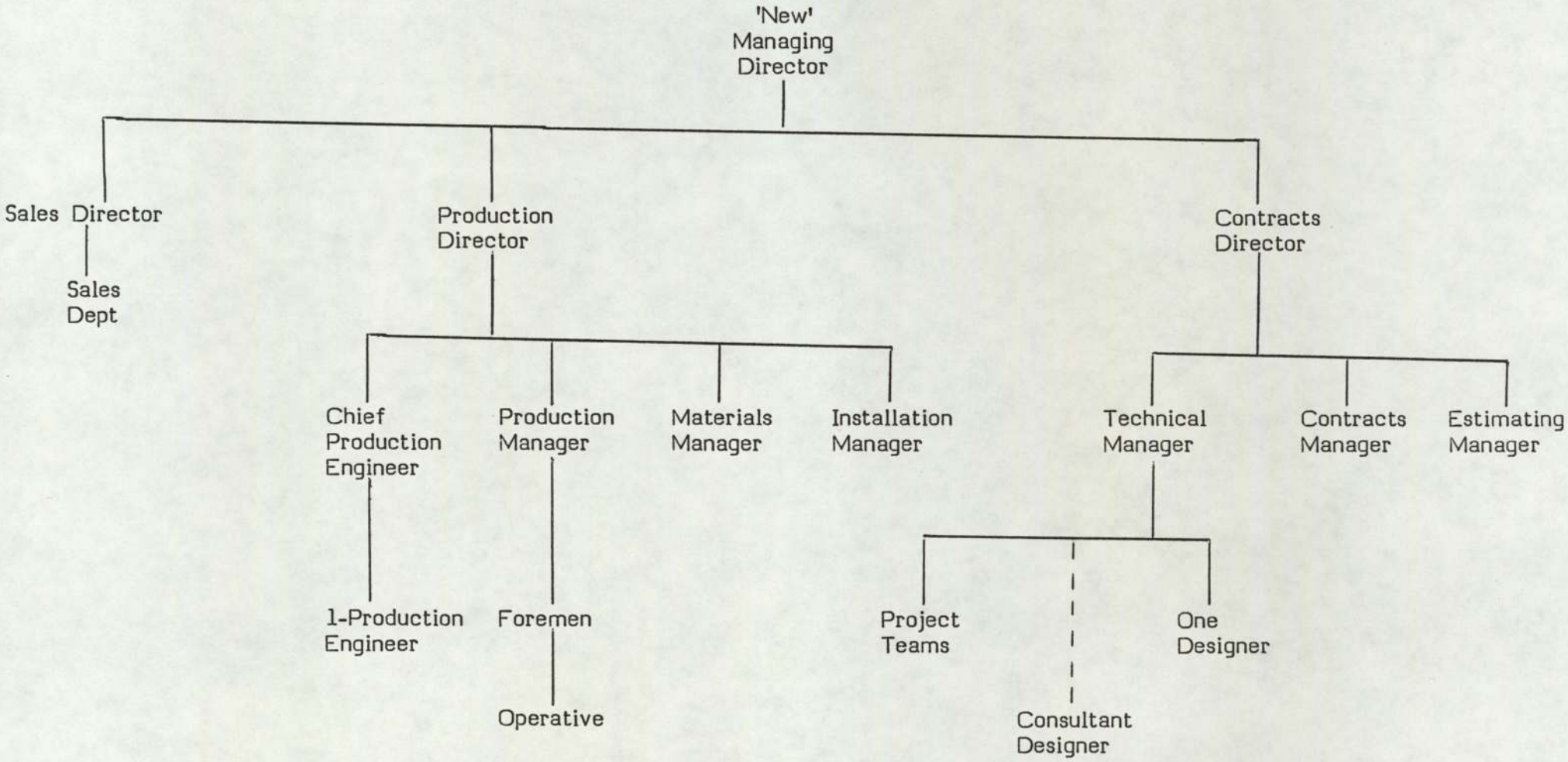


Figure Apx 12-3 - Reorganised New Simplified organisation chart of AF Limited

Appendix 13

SPM LIMITED

SPM Limited with a total workforce of 210, is organised into three divisions, namely Special purpose machines, Aircraft division and Automation division. In this case study typical design process in the Special purpose machines division is considered. The machines designed and manufactured in this section are mainly for automobile industry. These machines serve a very specific function for example, drilling or boring of cylinder heads or connecting rods of engines. The machines are usually used for mass production of components in the motor industry and therefore have to be very reliable, efficient and durable. To achieve high quality products desired by the customer - the company employs a number of experienced and highly qualified engineers..

Product Specification

The process leading to a Product Specification is usually initiated when an automobile manufacturer enquires for a specific machine. This request takes the form of a commercial specification. This specification is usually prepared by the Customers Process Engineers, defining precisely the function and performance levels expected from the required machine. Also often with the specification, they also attach sketches outlining the type of machine they envisit to be ideally suited to their needs.

This enquiry is received by the Commercial Manager, who vetts the information in liaison with Sales the Engineering Manager (also sometimes known as the Proposals Manager). A Proposals engineer is assigned to the project to investigate the relevant details to the project. A meeting known as 'Engineering Meeting' is held, attended by the Technical Manager, Commercial Manager, Sales Engineering Manager, Controls Manager, Works Director and Proposals Engineer to discuss the details of the project.

During the meeting a print of customers drawing is thoroughly looked at and a number of possibilities relating to the requirements are critically discussed and debated. All those present convey their ideas or opinions by writing on the drawing. Formal minutes of the meeting are not kept but the comments on the drawing serve the same purpose. The primary aim of the meeting is to agree on the engineering concept of the product.

Drawings with the comments are passed onto the Estimating department to arrive at the estimated price for the project. This is then sent to, the Commercial Manager who arranges a meeting known as the 'Pricing Meeting' attended by Commercial Manager, Sales Engineering Manager, Technical Manager, Controls Manager, Works Director, Sales Director and Managing Director. Here the details of the estimated price are debated and these are broken down into man-hours spent by staff of each department. Each individual carefully examines the estimated input by their department and amends the information if necessary.

Finally a price on the whole project is agreed and signed for by each departmental head with any remarks or foreseeable problems they envisit.

However there is a considerable degree of formal and informal discussions and exchange of information amongst various members of the organisation in between the meetings.

In parallel to this the management of the company attempts to find out the amount of money available in the customer's budget for this particular machine. Hence the quoted price can be adjusted accordingly to enhance the chances of winning the order.

A quotation is submitted to the customer with all the relevant details on technical, financial and delivery aspects of the project.

It is normal practice for a customer to re-approach SPM Limited and seek mutually agreeable changes. When all disagreements are resolved an order is placed. The details of the final quotation are transformed into a Product Specification.

Design and Development

After receipt of an order a 'Handover Meeting' is held attended by those present at the 'Pricing Meeting' to discuss the details of the project with any specific clauses in the order etc. As well as finalising the details of the product specification.

The project is then formally handed over to the Technical Manager who responds by assigning a Project Engineer to carry out design and development work. Technical Manager however keeps a strict control on the program of the project by means of PERT and Bar charts.

Project Engineer prepares a schematic drawing in close liaison with the Estimating department to ensure that initially agreed estimated price does not exceed.

These drawings are reviewed and discussed internally in the firm before forwarding them to the customer for approval and comments. Changes in the drawings may result at this stage; once these drawings are satisfactory, detail design process is initiated by engaging outside contractors - as SPM Limited does not employ detail designers.

The Project Engineers attempt to maintain a strict control on the project by visiting contractor's premises, often accompanied by the Planning Engineers. Once the detailed drawings are complete, the Planning Engineers formally take-over the project and commence planning for manufacture. There after manufacturing operations start and these are monitored by holding regular fortnightly meetings attended by Technical Manager, Works Director, Managing Directorand Sales Director.

Upon complete assembly of the machine a series of sequence and acceptance trial tests are performed in the presence of the customer. Then the machine is despatched to the customer.

Observations

The company is quite successful in achieving a product design which is compatible with the customer's needs by maintaining a close contact with the customer in the initial stags of the project. It also has a good formalised procedure from receipt of an enquiry to delivery of the machine. However during the course of discussions with the Technical Manager and the Works Director a number of points were highlighted:

- the company does not have Production Engineers and the Planning Engineers attempt to perform this role unsuccessfully. As a result the products are rarely designed with economic manufacture in mind.

- the company also does not employ detail designers, this task is carried out by contract detail desgin firm. Technical Manager said during the course of an interview, although we have had a long association with the contractors, still a number of deficiencies arise at the design/production interface. For example modification procedure is difficult to implement, as well as other problems regards communications, standardisations and control of the projects etc.

- the Technical Manager claimed standardisation is not possible due to one-off designs, but the Works Director stated otherwise. He said up to 30% components could be easily made common throughout the special purpose machines division by recruiting in the company Detail designer and Production engineers. In addition to this there is an urgent need for a good formal system of stock control and coding and classification of drawings. This in conjunction with greater emphasis on economic design of a product could considerably improve the efficiency of the whole design process.

- they both said that due to the recent reorganisation of the top management, these areas are being investigated.

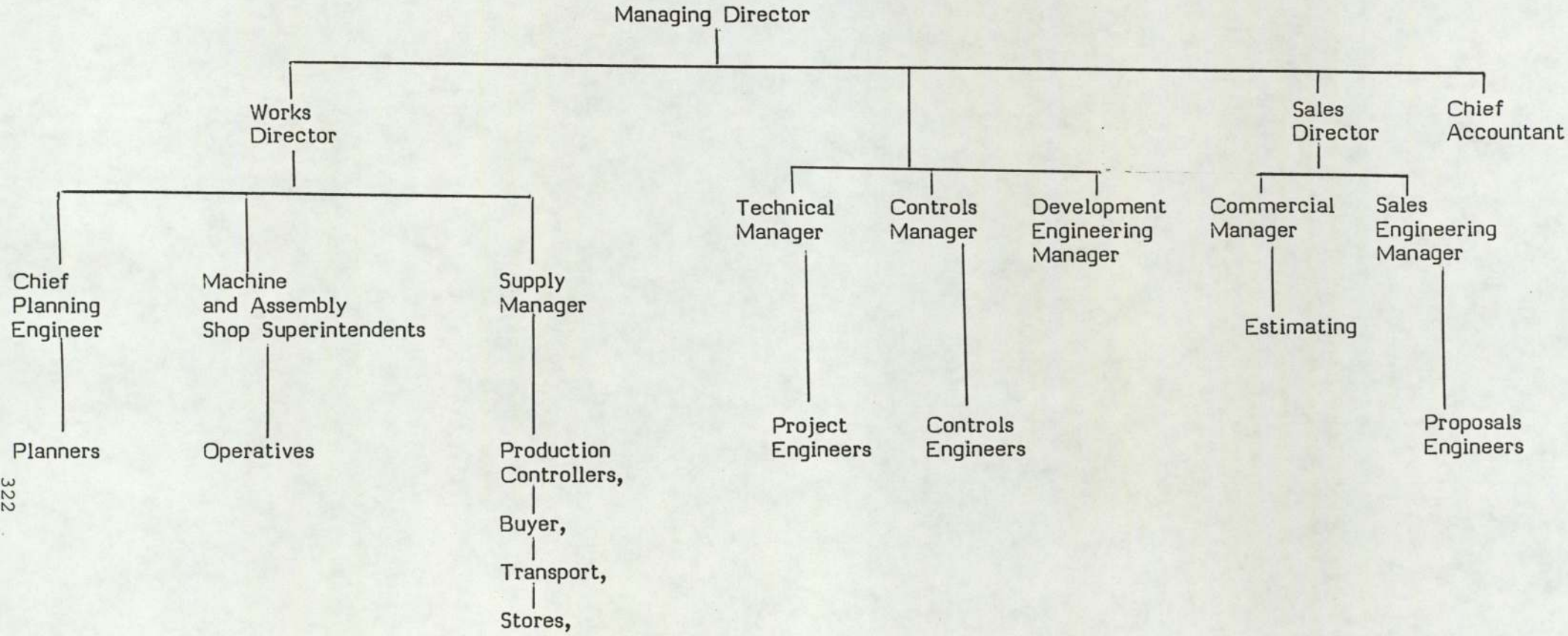


Figure Apx 13-1 - Simplified organisation chart of SPM Limited

Appendix 14

FCV LIMITED

FCV Limited, based in the West Midlands, was established in 1798 and moved to their present premises in 1970. It is believed to be the oldest engineering business in the area and is still owned and managed by decendants of the family that founded the firm. In fact, the present Joint Managing Director and Chairman is the seventh generation of the family to manage the firm.

The company specialises in the manufacture and development of fluid control valves from the smallest plug cocks to large and sophisticated thermostatically controlled hot and cold water mixing valves.

The company has expanded enormously since its outset, now with companies and sales agencies all over the world from the United Kingdom through the continent and the United States and on to Australia and Japan.

Its business has developed to satisfy the world-wide demand for quality products and up to the moment designs, along with the technical back-up that is needed to fulfil customer requirements and good working relationships.

The whole of the manufactuirng processes are located on the one site and products can be manufactured directly from the raw material through foundry process, on to machining, polishing, plating, assembly, test and despatch.

The company also specialises in special customer requirements, where the customer requires a particular valve or assembly to carry out a function required by them, as well as a range of standard valves which are held in stock.

In mid-1983 FCV Limited launched a new company to cater for the do-it-yourself trade. The 'NEW DIY Limited' also based at the same premises - producing a complete range of high quality bathroom and kitchen fittings specifically designed for DIY installation.

FCV's management saw the DIY sector as a growth market even in an economic recession, having examined the market and the market conditions overall to see what opportunitieis there were to expand business.

It seemed that there was a gap in the current range in presenting to the public a complete range of bathroom and kitchen taps, all attractively styled with matching headwork.

Product Specification

The Production Engineering department is the Technical department of the company. It is also the Quality control department and therefore undertakes all decisions relating to the monitoring of product quality. It is the responsibility of the department in conjunction with management, to lay down specifications and design on all new products as well as decide on the subsequent manufacturing operations.

Management of the company has a policy of continually reviewing their existing range of product and perhaps improve them. In fact 50% of the new products are as a result of marginal improvements. The other half of the new product design are initiated when the company responds to customer's specific applications.

Majority of ideas for product improvements generally originate from USA or from other European countries. When the company attempts to capitalise on somebody elses idea and market then under their own brand name.

The usual process for the initiation of a design project is when a meeting between the Managing Director, Chief Production Engineer, R & D Engineer and Development Engineer is held to discuss different options available and agree upon broad specification. At this meeting factors such as Product parameters, target price, prototype date, and detailed work programme etc are debated and verbally agreed upon. Usually R & D engineer and Development engineer make their own notes in order to assist them in their task and serve as future guidelines.

Design and Development

On the outset of a product design the original concept is transformed into working drawings. From these drawings the first prototype is made by hand in the Development department. The Development engineer, upon receipt of a new design, raises a product log book in which he enters all relevant information regarding the making of the prototype and testing.

The product is then rigorously tested to the agreed initial specification and all test details recorded. If any changes are made to the prototype to meet the specification or improve design all this is written into the log, giving a concise history of product development build up.

When the Engineers are satisfied that the prototype is exactly what is required, the product is tooled up for a pre-production batch to iron out any errors in production methods. The products at this stage are subjected to field testing and consumer approval. The results of these field tests are routed to Production Engineering department, via the sales force and service engineers. These are examined and any changes necessary carried out and entered into the Product Log book.

The product then goes into production and it is monitored through its first production batch by Production Engineering department to ensure that all methods and proceedures laid down in the specification are adhered to.

The case history of a time-delay push type tap is set out below.

Design process of a Time-delay push type tap

In the mid-1970's an energy saving campaign was launched by the government to promote greater awareness of diminishing energy supplies. Also the fact prices for energy and water were on the sharp increase. FCV Limited realised a market potential for a new type of water taps which would operate on a time-delay principle, such that tap turns off water supply automatically after a few seconds.

Production Engineering department in conjunctions with management devised a written design brief outlining broad parameters. However details such as project duration, target price and technical content are not specifically laid down.

Members of the Production Engineering department set to work on this project and following events took place thereafter.

Design and Development

1st Idea - between 1977 to mid-1979

After producing working drawing, the R & D Engineer constructed a prototype model. Initial tests were encouraging and further one-off were built in the development workshop. After rigourous tests, 60-65% success rate was achieved. Based on these events the management decided to go ahead with the project and authorised manufacture of production tools, at cost of approximately £15,000. During the pre-production run a batch of 100 taps were made.

Field tests were initiated, during its course a major design fault in the spindle of the tap was discovered. To rectify the problem numerous unsuccessful modifications were attempted.

Finally the management decided to abort the project and perhaps start again from first principle.

2nd Idea - Early 1980 to June 1981

During a visit to an exhibition the R & D Engineer conceived a new idea for the time-dealt tap. He discussed this idea with his colleagues, as a result a prototype was made. Initial tests on this were successful.

Tools were authorised, manufactured and a batch of 100 taps were produced.

Tests were carried out on 10 taps installed in the Works toilet, when apprentices were allocated the task of carrying out 100 operations each day.

Usually the company works on a principle that on average a tap would be used 20 times per day, for about 10 years.

The life of a tap is determined by the life of the spring and rubber seals.

Recommended life of a spring is approximately 150,000 compressions.

The required operational life of the tap is 20 operations x 7 days x 52 week x 10 years.

= 7280 compressions.

Since life of spring is about 150,000 compressions a tap should last either 2 years, or withstand 40 operations per day for 10 years.

3rd Idea - July 1981 - Early 1983

Managing Director of FCV Limited visited USA manufacturer of similar taps. He attempted to negotiate a deal to manufacture this tap under-licence in the UK but unexpectedly he managed to persuage the company to sell the internal functional mechanism to FCV Limited at a trade price. In fact on his way back to the UK he brought 20 mechanisms with him.

Production Engineering department re-designed the body of the tap - again an Engineer confesed that aethetic was copied from a leading continental design.

With the 20 mechanisms incorporated into FCV's body, a series of field tests were successfully undertaken.

The company commeneced full production in early 1983 and simultaneously launched the product onto the market.

The manufacturing cost of the present time-delay type of tap is approximately 50% less than that was set as a target price in the initial specification in 1977!

Observations Observations

Although on the surface the company appears to be quite well organised and effective in operation. The mangement boasts that it has good working relationships amongst its different functions in the organisation achieved through clearly defined duties and responsibilities of each individual. The process of design and manufacture and its associated information system is comprehensively laid out in a document known as Quality Control Manual. However the time-delay tap design history suggests that it has serious short-comings in the Engineering Department as well as in the field of Project Management

On the otherhand recent expansion of the firm into do-it-yourself trade indicates the management ability to foresee opportunities in the market and exploit them to their advantage.

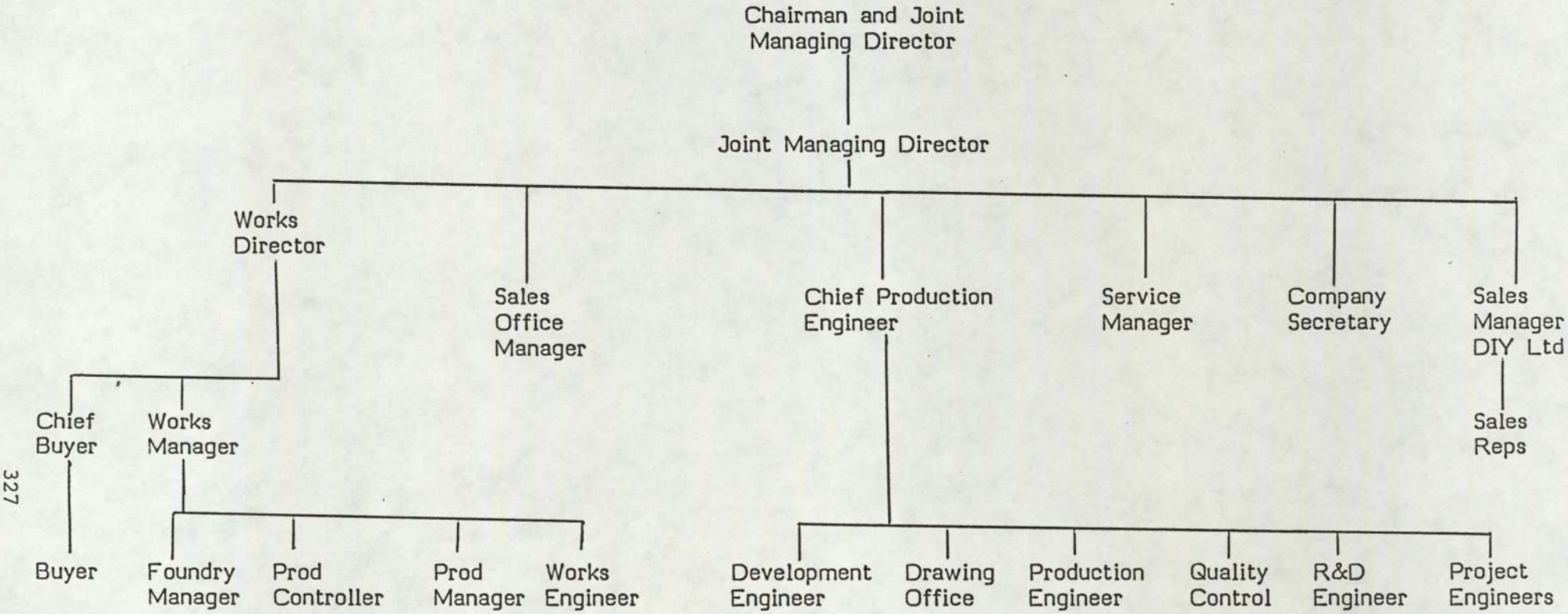


Figure Apx 14-1 - Simplified organisation chart of FCV Limited

Appendix 15

EE LIMITED

EE Limited based in Staffordshire is currently engaged in manufacture of dust, fume control and dust collection plant. It also offers a comprehensive installation service. The company employs about 70 people. The organisational chart shows the break-down of functions (Figure Apx 15-1).

Product Specification

Enquiry for a new product arrives at the company through different sources such as its own Sales and Installation departments or direct approach by the customer by means of letters or telephone etc. The enquiry is passed to the Engineering department who produce provisional drawings. Then the Sales Department and Estimators prepare a quotation which is submitted to the customer. If the details are acceptable to the customer, a firm order is placed. It is the current practice in the company to provide the designer with the copy of the order so that he can produce the necessary drawings from the order. There is no attempt made to convert the details of the order into a product specification.

Design and Development

Engineering department from the provisional drawings and ideas prepare a more detailed design. These drawings are usually produced in isolation from production department - who only get involved during the formal handover stage. It is then the Foreman or Superintendent who plan for manufacture and the construction of the plant commences.

Observations

A number of visits were made to the company, extending over a period of several months. During these visits a number of interviews were conducted with the Foreman, the Superintendent, the Designer, the Engineering Manager and the Work's Manager and as a result the following points were noted.

The foreman claimed that his involvement in the design process is purely by chance rather than intentional. For example, the only time he gets involved in the design process, is when he is passing through the design office and out of curiousity may start talking to the designer regards the project he happens to be working on. During the course of these informal dialogues he may make some suggestions regards its economic manufacturability. Other than this no attempt is made by either design or production to communicate with each other during the course of a project. The Foreman further claimed that the designers are usually unaware of production facilities, regards their capabilities, limitations and capacities etc. He supported his argument by citing examples about designers knowledge of capability or limitations of bending machine. He said frequently on the drawings they specify radius of bends for which neither they have the tools nor the machines capable of carrying out such bends. These claims were generally endorsed by the Works Manager and the Superintendent

and they further pointed out that all the assembly and detailed engineering drawings consists of three conventional elevations, ie front, side and top view. They argued that due to the nature of their business 3-D, isometric drawings would be more appropriate in a number of cases. This way the shop-floor operators could easily visualise the product whereas with the traditional engineering drawings, the operator has to use a lot of imagination to understand the drawings.

In contrast to these arguments, a number of design personnel were interviewed, they argued that it was not always possible to consider the production point of view because of strict time schedules on the projects. Due to the time restrictions imposed on them by the management and the customer, design for production becomes a secondary factor and as a result inadequate attention to factors like standardisation and economical manufacture is paid. In fact one designer, during the course of discussions admitted that he felt 'ill-equipped' to consider production features during the design process and he would feel 'ashamed' if he had to seek advice from production. This is because we, as designers, are considered to be of higher status and expected to 'know it all'. In fact we are inadequately informed about production, and the situation is so bad that we feel 'ashamed' and reluctant to visit the shop-floor. As a result of this inadequate communication between design and production exists, leading to uneconomical designs and very often conflict between the two functions. This designer blamed the management for the current situation and the initative, to improve the relationship between the two departments. has to come from the management.

In addition to these points, observations during a period of several months revealed that the company is poorly organised in many aspects of its operations. For instance, in the area of formal guidelines for the designers from the standardisation point of view and from the stock availability point of view. In the case of standardisation it appears that standardisation of components is carried out by the designer by his own initative and judgement without the assistance of any formal guidelines and in the past this has lead to duplication of components and drawings etc. Also no system exists regards stock availability on the shop-floor or in the stores as a result some of the components are over-designed. For example, due to lack of information on existing stocks in the stores, the designers tend to use unnecessorily thicker gauge material as opposed to using the least acceptable gauge thickness of sheet metal.

This argument was also found to be true with regards the availability of the tools to manufacture the products - the designer did not have any information on the types of tools currently available on the shop floor or in the stores etc.

Those interviewed felt the situation could be improved as follows:-

- Since the Designers lack production experience, if they were to spend a few weeks in the workshops familiarising with the facilities available and method of operation, this will be of invaluable benefit to the organisation.

- Regular meetings should be held with design and production regards progress of various projects.

- Management should encourage greater communication amongst its staff both formally and informally.

- Due to the nature of products manufactured, perhaps 3D drawings would be of enormous benefits in addition to the Engineering drawings.

- Standardisation should be encouraged by formal guidelines.

- Proper formal modification procedure needs to be introduced.

- A manual consisting of information on the facilities available on the shop-floor should be prepared and widely circulated.

- A general improvement of the administration system is required.

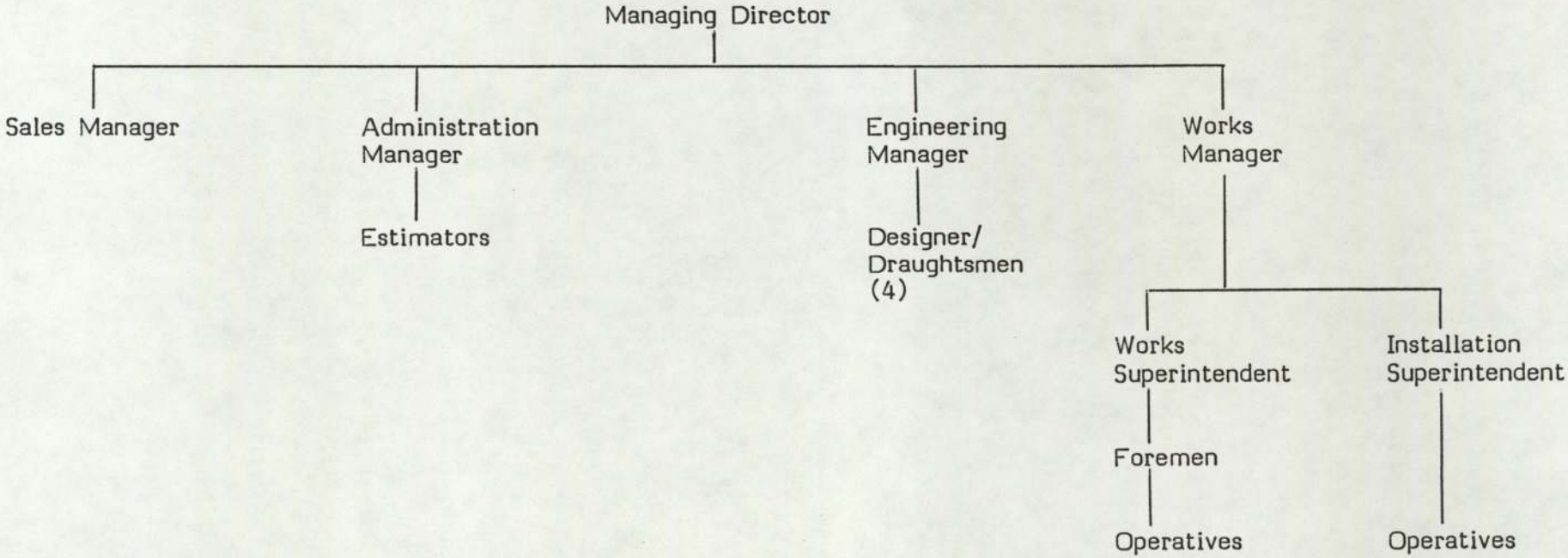


Figure Apx 15-1 Simplified organisation chart of EE Limited

Appendix 16

MBC LIMITED

MBC Limited, a family business, have been involved in motorcycles, racing cars and bicyles since 1895 when the grandfather of the present directors started a company to make motorcycles. The company is based in a modern industrial site in the West Midlands and currently employs about 50 people. The younger brother performs a dual role, that of a Managing Director and a Design Engineer. The other brother deals with the commercial aspects of the business. The Works Manager assist the Directors with the Production Engineering side of the product design as well as managing day-to-day shop-floor activities. The financial aspects of the business are dealt with by a part-time accountant.

The Directors, wish to retain the business as a family concern and have no strong desires to compete with larger manufacturers. Hence they tend to exploit smaller markets, which are not attractive for large companies.

One of the brothers owns a boat and the other flies a light aircraft. Both found difficulty with mobility on reaching their destinations. Their own need inspired the Managing Director to design a lightweight folding bicycle which would pack into a bag and be easily carried in a car, boat, train, or aeroplane.

In 1974, they formed a sister company especially to manufacture these folding bicycles. Full-scale production started in late 1976 and at present their production rate ranges between 100-150 cycles a week. Most of the sales are in the UK but many have been exported, mostly to the USA, but also to France, The Netherlands and Australia.

This bicycle which was designed essentially as a runabout and not a touring bike, is used by a wide range of people. The one model can be ridden as easily by a seven-year child as a six-foot man.

The folding bicycle has been very successful and it won a Design Council Award in 1978.

Using the same basic components and sub-assemblies the Managing Director has now designed a tandem which, although not foldable, has a wheelbase only slightly longer than a convential solo bicycle due to its small wheels.

So successful has the design been that the Post Office has commissioned MBC Limited to design a replacement bicycle for its present models thereby reducing the large number of variants it presently owns with corresponding spares stock problems.

The remainder of the case study describes the design process for the Post Office bicycle.

Product Specification

The origin of the design brief is usually from two sources. Firstly, as a described earlier in the case of the folding bicycle, when the management carries out market analyses and identifies a specific opportunity. The specification in this situation is devised collectively by the Managing Director, Sales Director and the Works Manager.

Secondly, when a customer approaches the company with specific requirements, as did the Post Office.

In the case of the Post Office, the Managing Director set about his task by initially reviewing the design of existing range of bicycles. Also he spent sometime with postmen in different parts of the country to determine the functional aspects of the bicycle.

From his initial market analysis he found Post Office bicycles with the following variables.

Existing ranges of bicycles consisted of:

6	Frame Size
2	Speeds
2	Types of carriers
4	Types of saddles
4	Types of pedals

This gave 384 possible combinations.

This made him appreciate the extent of stock problems which the Post Office faced.

From his market research he identified the basic requirements of the bicycle. He categorised the needs and reduced the possible combinations to 64. In collaboration with the Post Office, MBC Limited produced a product specification acceptable to both sides.

Design and Development

The initial ideas laid down in the specification were converted into a proto-type model. These prototypes were supplied to postmen and women in the different parts of the country for trial tests. The performance of the bicycles were strictly monitored by the Managing Director. This entailed a number of modification from time to time in an attempt to optimise the performance.

During this process the members of the company worked collectively and resolved problems as soon as they arose.

The prototypes are still undergoing field tests and the final decision whether to proceed with the project is still unknown.

Observations

The folding bicycle is a success story of a small company recognising a market need, designing for manufacturability, flexibility in one model fitting all sizes, good ergonomics and industrial design, and production of a thoroughly reliable

product with the designers being principals in the business.

However with the Post Office project it has not been all a success story as the project now has been 'ticking-over' for the last 4 tp 5 years. Not due to any shortcomings on the behalf of MBC's management but perhaps due to lack of enthusiasm in the Post Office. The Managing Director confesses he gets frustrated on a number of occasions, especially as there have been six changes with his contact in the Post Office during the course of the project. On each occasion he has had to start from the beginning and explain the details to the 'new contact'.

The relationship amongst the employees during the course of the project have been that of active involvement. Usually this in the past has had led to an effective product design process.

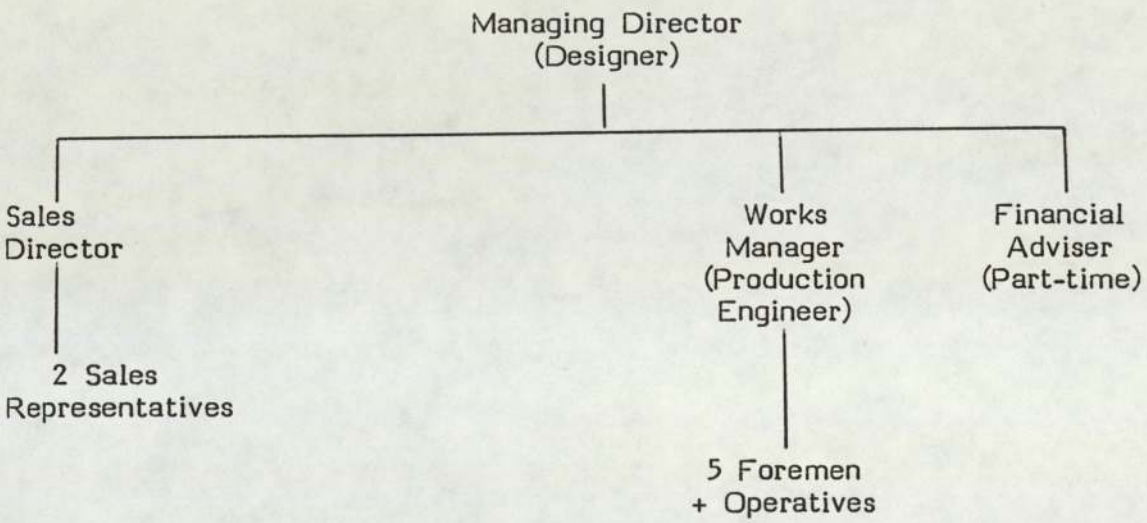


Figure Apx 16-1 Simplified organisation chart of MBC Limited

Appendix 17

HPE LIMITED

HPE Limited is based in the heart of the West Midlands and currently employs about 150 people. It manufactures a range of hydraulic power equipment such as rams, pumps, jacks and cranes etc. As well as manufacturing standard equipment it also makes products to customers specific requirements.

The company's strong engineering department is complemented by excellent workshop facilities and a good after-sales service. Over its 50 year history the company had enjoyed a good successful track record.

Product Specification

Product specification generally evolves from the following methods:

(i) Customer approaches the company with specific requirements .

Customer usually approaches the company in a number of ways such as through the sales representatives or by telephone or by letter. The details of the information provided by the customer, can range from a vague verbal outline to a comprehensively laid out written requirement.

The enquiry is thoroughly vetted by the sales department and then passed to the design department, who in collaboration with the estimators devise a preliminary quotation. A meeting is held at this stage when the Design Director, the Design Manager, the Designer, the Production Engineering Manager and the Sales Director jointly discuss the details and if necessary amend the quotation before submitting it to the customer.

Once the details of the quotation are agreed with the customer and then the content of this quotation are translated into the design brief.

(ii) Specification for a standard product

The sales department carries out a market survey to identify the customers future requirements. In fact usually the sales department has a considerable amount of data which they have collected over a long period of time in the form of sales reports, surveys and competitors models etc. The relevant information is extracted and jointly discussed by the Design Director, the Design Manager, the Designer, the Production Engineering Manager and the Sales Director. At this meeting all the relevant details relating to the new product are discussed and formally prepared into a product specification.

Design and Development

Designers usually have sufficient information to enable them to commence the design and development work on the project. During the design process regular formal meetings are held to monitor the progress of the project. At these meetings production are also represented. If there are any problems concerning the manufacturability of the product it is either discussed during the meeting or informally after the meeting. Design process continues in this way until the drawings are handed over to the production department. They carefully check the drawing to ensure that components can be manufactured economically before commencing design of jigs and fixtures. At this stage, however, extensive consultation takes place and often leads to amendments to the drawings.

When jigs and fixtures are made, the product is planned for production and finally full scale operation begins.

Observations

A formal means of communication between departments exists. This generally leads to an effective product design. The relationship between design and production functions are good with an utmost emphasis on collaboration and coordination during the design process.

However during the course of an interview with the Production Engineering Manager, he revealed that a number of the designers lack appreciation of the production processes and in general are reluctant to explore the shop-floor facilities. He believes that designers training methods could be significantly improved. He felt they need to undergo some sort of training in production methods prior to their appointment as designers.

In this company, however, some of these weaknesses are compensated by good communication to ensure that products are designed for economic manufacture.

Appendix 18

LTT LIMITED

LTT Limited, part of a giant engineering group is based in the Midlands region. It currently employs about 200 people backed up by its excellent fabrication and machining facilities. The firm makes a comprehensive range of all types of tank transport and aircraft refluellers, for all types of major oil, petrol, food, milk, chemical and haulage companies in the UK and overseas. In addition to this it also manufactures truck mounted concrete mixers.

The company have been building tanker fleets for well over fifty years and are the United Kingdom leaders in bulk liquid transport. As well as supplying standard design tankers it also specialises in making tankers to customers requirements.

The management claims that the company has a reputation for efficiency and reliability known throughout the world and proof of this is shown by the fact that after so many years the same customers returning with further orders.

Product Specification

The customers usually approach the company with its requirements. The sales department of the company responds by requesting the customer to complete a standard questionnaire - thus extracting all the relevant information. The copy of the completed questionnaire is circulated to the General Manager, Works Manager, Technical/Sales Manager and Project Engineer. The Project Engineer prepares preliminary drawings of the requirements and discusses the details with the aforementioned managerial staff and jointly they arrive at the estimated price. A quotation to the customer is then submitted.

If the order is placed then the details prepared earlier are translated into a Product Specification - incorporating only basic outline parameters of the project.

Design and Development

The Project Engineer embarks on the design work and produces the necessary drawings. The progress of the design work is monitored through regular formal meetings as well as through informal dialogue. When the design work is complete - the Project Engineer produces 'technical specification' to enable shop-floor workers to commence manufacture. The 'technical specification' is formulated with the help of the Production Department and it includes information on materials to be used and method of manufacture etc.

The Project Engineer remain overall in charge of the project through its various phases of manufacture, inspection and tests etc.

Observations

The company has a well laid out and a concise method of obtaining information from the customer. Thereafter Project Engineer is completely responsible for the destiny of the project - the quality of the product design and its subsequent and economic manufacture is dependent upon the calibre, concentioness, effort and enthusiasm of the Project Engineer. This is why the General Manager claims he is very careful when recruiting Project Engineer, due to the enormous burden they carry. He believes that Project Engineers in the company are of high calibre and as a result given high status - in fact they are the highest paid personnel in the company after the managers. Project Engineers, are constantly working, under pressure and to extremely tight schedules and are continuously expected to be creative as well as being cost conscious.

He claims there is a grave shortage of good Designers/Project Engineers in the UK perhaps due to inadequate credit, respect and status given to them for huge responsibilities they carry. For this reason the company has a long term policy of training their own Designers/Project Engineers through an apprenticeship system - so that the company achieves their own desired standards.

The Works Manager during the course of an interview was somewhat against the idea of giving a high degree of authority to the Project Engineers. He believed that it was unfair and perhaps unwise to expect a Project Engineer to be expert at all disciplines such as Product Design and Production systems.

He said the majority of the products designed are not economical to manufacture and are commonly over-designed with inadequate regard for production. Since the Project Engineer is handling 5 or 6 projects simultaneously - they tend to overlook or ignore details - thus leading to numerous modifications during the manufacturing stage. He strongly felt a real need for Production specialists who would be experts in manufacturing techniques - they would liaise and constantly advise Project Engineers on up date production technology available. By recruiting Production Engineers into the organisation significant improvements could be made in the product design, from the manufacturing point of view.

On the question of standardisation policy on new product designs - the General Manager said that due to the special nature of their product - it is difficult to standardise. Project Engineers attempt to use their own iniative rather than working to any specific formal guidelines. However he confessed that between 10-20% of the components used in new designs could as easily standardised if a formal system was introduced. It was his intention in the near future to introduce a formal system so that optimum number of standard components are used in new designs.

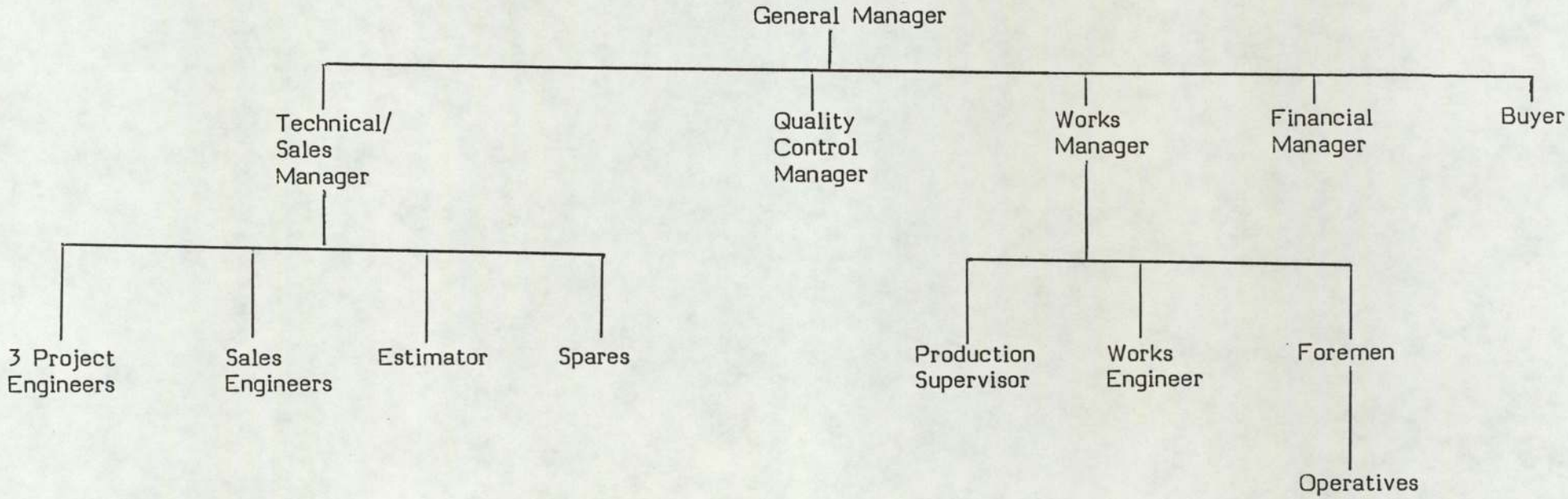


Figure Apx 18-1 - Simplified organisation chart of LTT Limited

Appendix 19

APR LIMITED

APR Limited employs 100 people and is engaged in the business of design and manufacture of air pistols, air rifles and starting pistols. The company has a long and successful history and a world wide reputation in the field of high quality pistols. Currently it has a best selling air pistol in Europe.

Strictly speaking the company does not have a policy of introducing new products at a regular interval but it usually responds to decline in their shate of the market by engaging itself in the process of new product design, which entails changing the aesthetic featues.

Product Specification

When the company realises the need for a new product. It usually employs the services of a market reseach company to carry out a survey and identify market needs and tastes etc. If the research indicates a gap in the market then the management discusses the relevant details and initiate a new product design process.

There are three basic techinical features in the product specification which are needed to be satisfied.

(1) Reliability
In order to enhance the reliability attempts are continually made to reduce the number of functional components. This also means customer has fewer parts to maintain and service.

(2) Appearance
Appearance is continually improved to increase attractiveness, and appeal of the product over their competitors.

(3) Power
Although customer always desires a more powerful pistol or rifle but the maximum power permissible for a given product is strictly controlled by the government regulations. Power in a pistol or rifle is given by the Kinetic Energy of the pellet or bullet. For example:

Kinethic Energy = $\frac{mv^2}{2}$
where
m = mass of the bullet or pellet in Kg
v = Velocity of the bullet or pellett in m/s.

The kinetic energy can be changed as follows:

(a) Either one can increase or reduce the mass of the bullet or pellet, or
(b) One can change the mechanical configuration of the pistol to change the velocity of the bullet or pellet.

When devising a specification these three basic technical factors are always considered. Of course there are other non-technical aspects such as target

price, date of launch, and budgets etc, which are also considered. Based on the above information design brief is prepared to enable the design department to commence design and development work.

Design and Development

At the start an artistic impression of the new model is produced by an outside Consultant Industrial Designer. Different ideas are presented to the management team consisting of Technical Director (Chief Designer), Manufacturing Director, Works Manager, Managing Director, Sales Director and Financial Director. They all discuss these ideas and make comments, amendments as necessary. When an aesthetic design is agreed upon, the design departmnet produces provisional drawings which are then handed over to production engineers for evaluation of each component.

During this process numerous modifications occur. If however there is a disagreement between the two parties over a particular point - then a meeting is held between the two involved and the Managing Director, Manufacturing Director and Technical Director assist in the decision making process.

When a final design is agreed by all those concerned, Production engineers are formally handed over the drawing to commence planning of manufacture and design jigs and fixtures etc.

The actual design process from inception to completion usually takes about 12 months and from the issue of provisional production drawings to production engineers to start of manufacture it takes approximately 8 months.

Observations

The company has recently adopted a policy of obtaining optimum standardisation on all their models. Therefore each component on all the products are thoroughly investigated and justified. For example their recent introduction of two air pistols on the market has 90% parts which are common to each other. Parts like trigger has been standardised throughout a range of pistols.

An interview with the Works Manager revealed the following basic problems which need to be controlled more carefully in the future.:

(i) Designer frequently gives inadequate attention to detailed design.

(ii) Designers from time to time tend to exploit technology and are keen to innovate with undue attention to economic manufacturability.

(iii) Occasionally designers become over-enthusiastic and wish to see the end result quickly, thereby in the process tend to overlook very important factors.

Company's organisational structure is designed in such a way so that Proruction Managers, Production Engineers and designers are all of equal status. This is reflected through similar salaries, qualifications for the jobs etc.

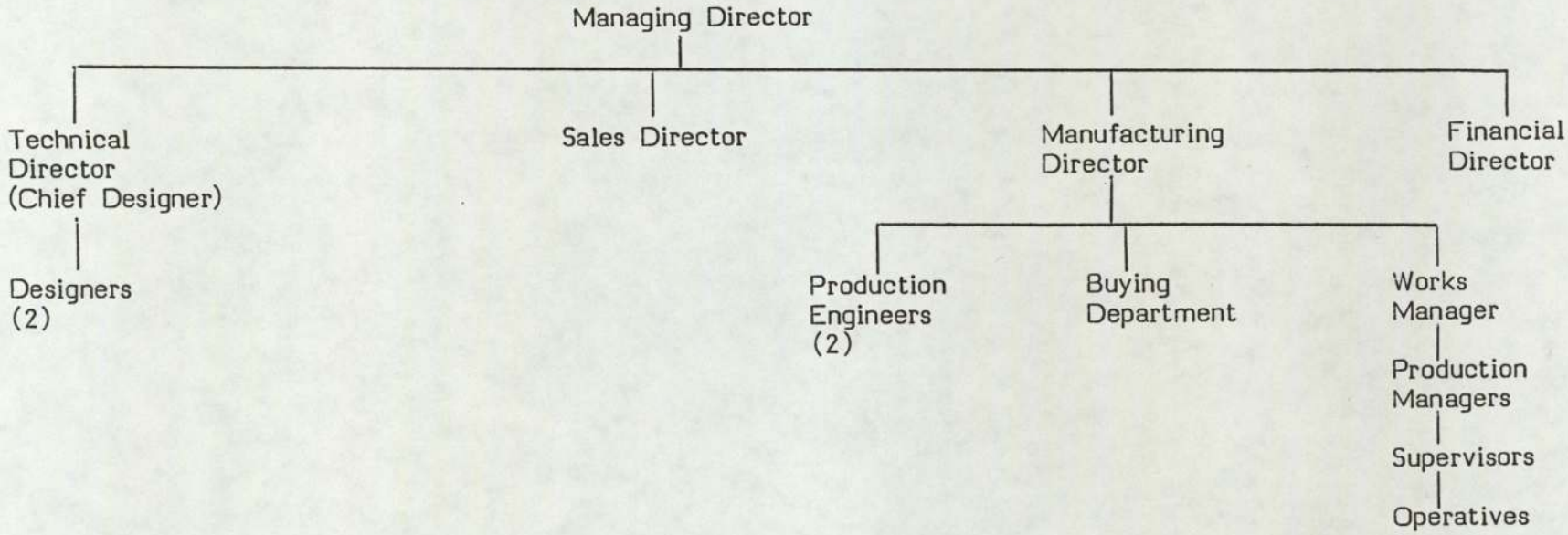


Figure Apx 19-1 Simplified Organisation Chart of APR Limited

Appendix 20

LA LIMITED

LA Limited, with only 60 employees, is a small family business engaged in manufacturing lifting appliances such as hydraulic and mechanical jacks, as well as lifting tackles. The jacks are normally produced as standards and only occasionally does the company indulge in making 'specials' to meet customers' particular needs.

Being small is size the general running of the day to day activities are left to the Works Manager, who is also responsible for product design from its inception to delivery. The company employs only two draughtsmen and also uses the services of a computer, where all the information regarding different variations to the product range are kept. The production enginerring input to the products comes from either the Works Manager or the Machine Shop Foremen.

Product Specification

Since the majority of the enquiries for the new products, which are usually scaled up - or scaled down version of standard items, the specification in principle does not vary considerably. The customer usually specifies the basic requirements and design department responds by feeding the information into the computer, which in turn indicates the precise parameters of the product. Based on this information the Works Manager produces an estimated price and delivery date and this is then submitted to the customer.

Design and Development

When a firm order is placed, the relevant information is again fed into the computer to produce drawings. If any drawing that cannot be produced on the computer, these are done by the draughtsmen.

The basic concept of the product remains same therefore virtually no modifications occur whilst product is undergoing manufacture.

Observations

This company has invested well in the computerised system, thereby reducing the possibility of error to the minimum. In this respect LA Limited is unique in its operation, brought about by a specialised nature of its products.

Appendix 21

SG LIMITED

SG Limited is part of a huge electrical group of companies, however, on its well equipped site in Staffordshire it employs 620 people. The company has a long history in manufacturing high voltage switchgear for UK and overseas markets. It enjoys a world-wide reputation for manufacturing, supplying, commissioning and after sales service in the heavy electrical sector of industry. A privately owned firm, it merged with another major electrical group of companies in the late 1960's. Since then a reorganisation of a huge scale had taken place in order to improve its effectiveness in a fiercely competitive fields. Strictly speaking SG is quite independent, financially and managerially, from its sister companies in the group but occasionlly it undertakes joint ventures with them in order to compete against overseas firms from West Germany, Italy etc.

The company's products can be broadly categorised into three main areas:

(a) oil circuit breaker
(b) air circuit breaker
(c) gas circuit breaker

Although the fundamental concept or principle of the product remains unchanged but generally speaking each enquiry or order has different functional requirements hence each project has to be individually engineered to suit customer's needs. Therefore virtually each product leaving the site is different.

The company traditionally has had a strong R & D department which is probably the most advanced laboratory of its kind in the UK, if not in the world. The laboratory is equipped with up to date modern technology to support its high calibre of engineers.

Major breakthrough in the basic functional aspects of the circuit breaker are rare but several incremental innovations occur quite regularly.

Product Specification

Usually an enquiry for a new project comes through different sources, for example, sales department, directly from a customer by letter or detailed specification, overseas agents and finally from sister companies in the group. The enquiry is then channeled through the sales department to the engineering department. Chief Engineer assigns engineer(s) to the project, who investigate its viability and applicability with help from the estimating department. Details and the implications of the enquiry on the production system are determined together with the estimated price and delivery. Sales department then transmits the information in the form of a quotation to the customer.

Customer examines the content of the quotation and this usually leads to a number of amendments and finally SG Limited and customer mutually agree on the final details. These details are then converted into a Product Specification, to enable the engineering department to commence design and development work

on the project. Up to this stage production is considered as a service department, ie to provide information as and when required by the engineering department. For example, the earliest possible date when they could programme this 'new order' into their production schedule. In fact it is the production management who generally responds to these queries and they determine the implications of this enquiry on the production systems, such as shop-floor layout, loading system, number of employees and shift pattern etc.

Otherwise the engineering department determines the details of the Product Specification.

Design and Development

The Chief Engineer/Engineering Manager assigns Design Manager and a Senior Design Engineer to the project. They act as a co-ordinating team throughout the design and development stage, The project is then divided into small sections and relevant work is passed onto Mechanical, Electrical and Electronics engineer. They perform their assigned tasks by producing sketches, and drawings etc. These ideas are transformed into proto-types which are tested extensively using development workshop facilities and also by carrying out simulation tests. When the functional details laid down in the design brief are complied with, the project is then handed over to the Engineering Services Manager. He instructs his staff to carry out detailed design - this usually results in frequent consultations with Senior Design Engineer in-charge of the project.

During the detail design process liaison with production department is infrequent and intermittent. Extent or degree of consultation between the design and production staff depends on individuals involved, whether a draughtsman has a good working relationship with his production counterpart. If the relationship is good then product will be designed with economy in mind. If it is not then the liaison is usually uncommon and rare which frequently leads to uneconomical product design.

However the usual procedure is to complete the detailed design and then handover the drawings to production. Production department carries out production planning process and designs jigs and fixtures as necessary. During this process frequent meetings between the designer and production functions are not uncommon. Any modifications arising is through the process of 'hard-bargaining'. For example production may claim tolerances or finish specified on a component is not possible with the existing facilities - hence they will seek concessions. A considerable debate usually result before amendment occurs.

During the production planning and manufacturing stage a considerable number of modifications to components arise.

Observations

During the course of an interview with the Manufacturing Manager he claimed that a 'large chunk' of the product cost is completely unnecessary if a closer working relationship between design and production staff existed then the product cost could be reduced considerably. Liaison amongst the members of the two functions, at the moment is quite poor. He believes this is because the whole organisation is centred around the engineering department and very little emphasis placed on other functions in the company. For example Engineering

department has traditionally dominated the design process and controls the ultimate destiny of the product. As a result they believe performance of the product to be the utmost important factor and design for economic manufacture is only a secondary concern. The engineering department has created an 'impreginable empire' which is very difficult to penetrate. As a result they enjoy a superior status, in terms of attitudes, qualifications and levels of salaries paid to them.

He further claimed the majority of the products are over-designed with inadequate consideration given to cost. He said that the designers are treated like 'god' in this company to such an extent that production personnel suffer from inferiority complex.

Any changes which takes place in the product design is through hard-bargaining/negotiations - even then it is a question of the strongest survives and the weakest simply capitulates.

Traditional attitudes and beliefs within the engineering department are very strong indeed - perhaps due to management's own short-comings. The reason for this is that over the last six or seven years the Engineering Director, Chief Engineer, Senior managers and Senior designers have remained unchanged. Whilst over the same period the Manufacturing Director, Manufacturing Manager, Chief Production Engineer and Shop Floor managers/superintendents have changed office six or seven times. As a result when a new Production Management team is appointed they have to start from scratch whilst engineering management has a significant advantage over them regards company system and knowledge of the product etc. The production management up to now have been unable to get to the 'root' of the problem in order to improve the situation.

Now, the Manufacturing Manager claims, the situation is in hand and he hopes to commence a series of value analysis exercises on the existing products and thereby 'educate' designers in the concept of Value Engineering. So that in future products are designed with economy in mind.

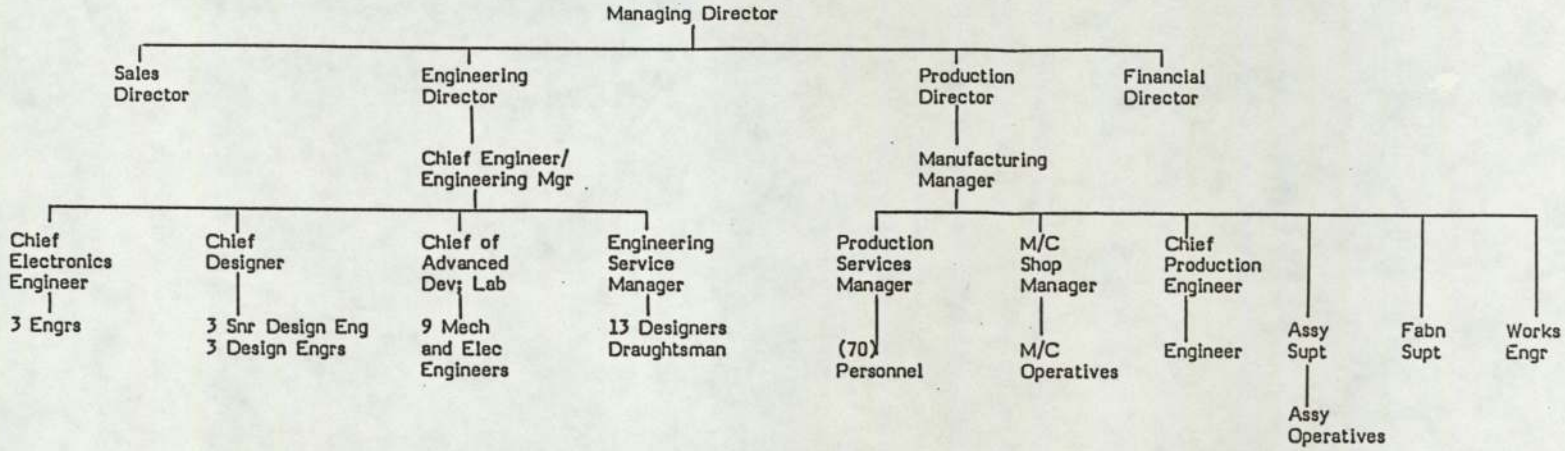


Figure Apx 21-1 Organisation Chart of SG Limited

Appendix 22

WA LIMITED

WA Limited is a constituent part of a National Engineering Company, based in the Midlands area. A small business employing only 70 people, it has a strong engineering department complimented by excellent modern workshop facilities. WA Limited designs and manufactures friction welding machines, single or double ended from 15 - 250 tonnes capacity suitable for welding a wide range of components with similar or dissimilar material combinations. Special custom designed fricition welding machines with automation upset removal and quality monitoring facilities. As well as designing and manufacturing fricition welding machines it also offers a sub-contract service for customers in batch production.

Product Specification

Usually a new project is initiated when the customer approaches the company through an agent or the sales department either in the UK or overseas, with a possible new application for a machine. This request is passed to the Manufacturing Manager for detailed investigation. He holds a 'Brainstorming session' attended by Mechanical, Electrical and Metallurgical Engineers, and one independent person from a different department such as Buying or Estimating. The Manufacturing Manager usually acts as a chairman to the meeting. At the end of the session an initial specification is prepared outlining broad parameter of the new machine.

An Application engineer is then assigned to the project to carry out a detailed investigation within the broad outlines laid down. After about 3 months he prepares a feasibility report which is vetted by the management team regards the viability of the project.

If the management wishes to proceed with the project, a Development Engineer takes over the project and initiates development work based on the guidelines suggested in the feasibility report. In fact the content of this report acts are converted to Product Specification, which includes all the technical parameters as well as financial constraints and time limitations imposed on the project.

Design and Development

Development Engineer liaises both formally and informally with Production and Buying departments to produce a functional design. At this stage his 'sole' aim is to produce a machine capable of performing customers desired application.

At the end he prepares a report based on his findings which includes technical as well as financial details.

Manufacturing manager along with the General Manager and the Sales Manager compare and contrast the findings of the Applications Engineer's report and Development Engineers report. Based on their findings they determine the saleability of the machine.

It is at this stage when an estimated price is calculated and a formal quotation

submitted to the customer. This is about one year after the customer initially approached the company.

If the customer and WA Limited mutually agree on the financial and technical details of the machine a firm order is placed. In fact it is at this stage when the final Product Specification is agreed upon.

Detail design commences - typically it takes about six months to complete all the necessary drawings - as there are some 2000 components on the machine. When the drawings are complete the Manufacturing Manager arranges a Value Engineering meeting attended by Mechanical, Electrical, Metallurigical and Production Engineers as well as Purchasing, Shop-Floor representatives and inspection. It is claimed that about 30% savings are usually made as a result of this session. When each component is value analysed until all those involved agree that further savings are not possible. This usually results in considerable changes to existing drawings.

The detailed drawings are then formally handed over to the Production Engineering department to plan and subsequently commence manufacturing operations.

Observations

The company is well organised and run quite efficiently. Micro-computers have recently been introduced in the company thereby minimising unnecessary routine work. Manufacturing Manager claims as a result of this, efficiency as a whole has improved considerably. The modification procedure is very strictly controlled by the management. Any changes have to be recorded on a change note which is circulated to all the departments for their comments and approval. When a drawing is amended, the Foremen or Production Engineers personally ensure that a latest issue of the drawing exists on the shop-floor.

The management claims although standardisation is difficult to carry out due to one-off products manufactured by one company this area is always borne in mind when carrying out Value Engineering exercises.

The Design Engineering staff are of significantly higher status then anybody else in the company except management.

Design/Production relationships are satisfactory for the following reasons.

(i) the size of the company is small, as a result informal relationships exist with emphasis on good communications amongst the personnel.

(ii) there has been a very low turnover of employees in the company for the last 5 years and management structure has remained unchanged as well. Therefore everyone is fully conversant with each others method of working - thus leading to a good working relationships.

(iii) Design department personnel through their training and experience are reasonably conversant with the shop-floor facilities. This situation is very much improved by the existence of a comprehensive manual consisting of capabilities, capacities and limitations of machines, plant and tools etc. A

copy of this manual is available to the design department as well as others in the organisation. In addition to this Production Engineers work closely to design staff on all projects.

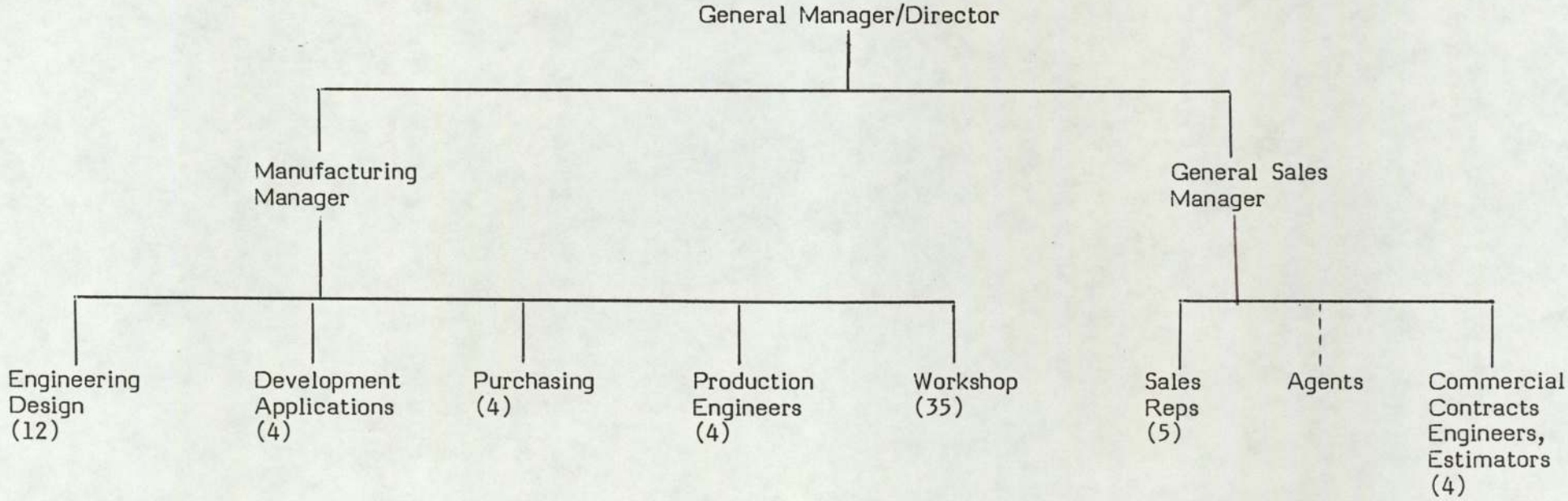


Figure Apx 22-1 - Simplified organisation chart of WA Limited