CoA Memo No. 186

COLLEGE OF AERONAUTICS

(Proposed Cranfield Institute of Technology)

DEPARTMENT OF PRODUCTION ENGINEERING

AUTOMATIC ASSEMBLY DESIGN PROJECT 1968/9

REPORT OF TECHNICAL SURVEY COMMITTEE

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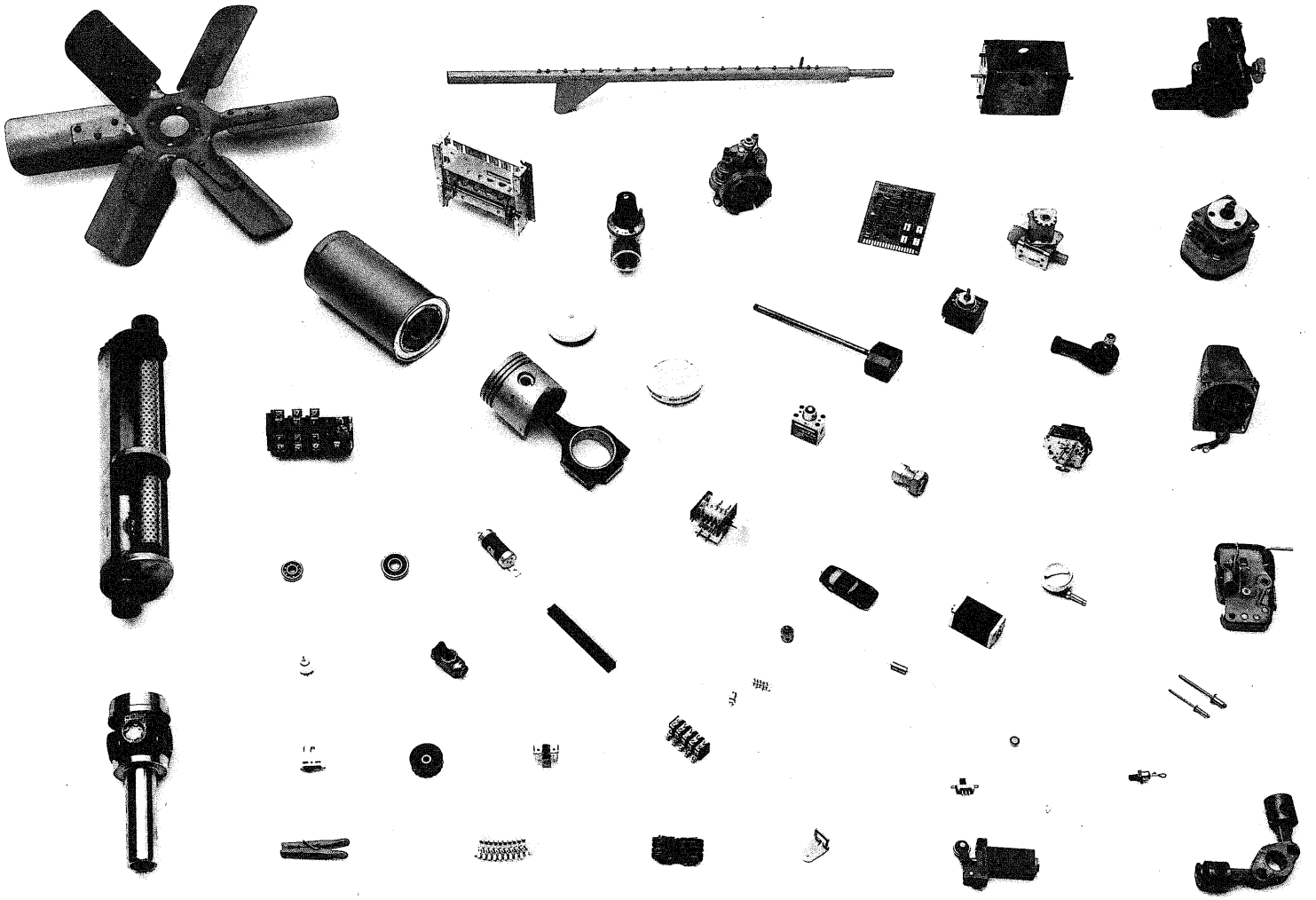
SUMMARY

An Industrial survey has been carried out to determine the desired features of an automatic assembly machine.

A questionnaire was circulated to industry and the results of the 38% response obtained were analysed and plotted. From these, conclusions were drawn as to the industrial requirements of an assembly machine.



SAMPLES SUPPLIED FOR TECHNICAL SURVEY

ACKNOWLEDGEMENTS

The Technical Survey Committee would like to thank the 265 companies who contributed the information which was used to produce this report.

The Committee would also like to thank Mr. R. Iredale, Deputy Editor of Metalworking Production, for his invaluable assistance in the preparation of the Technical Survey.

1.0 Introduction

At the first board meeting of the Design Project a Technical Survey Committee was formed to investigate industrial requirements. Although the prime interest of the board would be concerned with the design of a machine to assemble switches, it was felt worthwhile to determine the requirements of industry for an assembly machine. From the information received, it would be possible to determine whether the machine to be designed would satisfy the major requirements of industry.

The terms of reference of the Technical Survey Committee were, therefore, to determine industrial requirements for an automatic assembly machine and thus establish whether the machine to be designed satisfied these requirements. The survey would show how the flexibility to be built into the machine could be used to satisfy as large a market as possible.

As was shown to be necessary by the surveys of previous design projects (ref. 1), a pilot survey questionnaire was formed and sent to forty people, selected from industry and the Department of Production Engineering at Cranfield. This supplied information to make the actual questionnaire easy to understand and complete. A letter accompanied the pilot survey questionnaire explaining the project and asking for comments on the clarity, precision, and ease of answering each question.

The twenty replies to the pilot survey questionnaire were analysed and the information obtained was used to prepare the final questionnaire (Appendix I), which was sent to seven hundred companies in the United Kingdom.

Samples were requested and a good response was received as samples were included with 65% of the completed questionnaires.

A letter was sent to remind all those who had not replied six weeks after distribution of the questionnaire.

The response to the survey is shown below with the rate of reply given in fig. 1.

Number of completed questionnaires	89
Number of letters	176
Number of samples	58
Total percentage of replies	37.8
Percentage of completed questionnaires	12.7

The replies to each question were analysed and histograms were plotted to show the results (figs. 2 - 10).

2.0 Formation of Pilot Survey Questionnaire

To form the questionnaire, the committee had to decide upon the information that would be necessary to establish the requirements of an automatic assembly machine. By discussion and inspection of many products, a number of topics were determined about which information was required from industry.

From the results of previous surveys, it was obvious that one of the most important features of any survey is the method of questioning. The person answering the questionnaire must be required to do as little work as possible, yet the answers must give all the required information.

The general points that had to be remembered when forming the questions included:

a) Must be brief and to the point.

b) Each part must require only one answer.

c) Must only ask for facts which can be easily obtained from company data.

d) Must be worded and spaced such that they are simple to understand and answer.

e) Must be in logical sequence and the questionnaire must be pleasing in appearance.

From previous experience it was decided that, wherever possible, the answers should be in the form of ticks in the appropriate boxes. If percentages were asked for they need not be related to company output. Also, two different percentages given by two companies need not mean that the greater percentage was the greater output. A figure was asked for where it was difficult to determine the limits of replies to a question.

It was also decided that the person answering the questionnaire should have the opportunity to give any information it was felt would benefit the design of an assembly machine.

Keeping all these points in mind, the pilot survey questionnaire was prepared. After each question, space was left for comment on clarity, precision and ease of answering.

3.0 Analysis of Pilot Survey

Twenty pilot surveys were returned (50%) but it should be noted that only three weeks were allowed for returns. A few replies were received after this date, but were ignored in the analysis.

The reasons for rewriting the questions, as shown in Appendix I, are stated below:-

The name of the person completing the questionnaire, his position, and the company for whom he was answering, were requested at the top of the questionnaire. The committee decided to limit the survey to an assembly containing 20 parts. Several of the pilot surveys returned indicated parts from 170 - 10,000 which was considered wholly unrealistic for automatic assembly at the present time. By limiting the number of parts to be assembled, sub-assemblies were brought into the range suitable for automatic assembly.

Question 1

It was decided to limit each survey to one product only, and not, as in the pilot survey, to percentages of completed assemblies. The reasons were: i) time involved in answering in percentages, ii) percentages were meaningless in terms of products suitable for automatic assembly. An extra size range was added for those greater than 10 in.cu. since the pilot surveys indicated that this was required.

Question 2

It was thought that the survey would be quicker to analyse if the question on number of parts was divided into equal sections. Also, it would have the effect of reminding those completing it that the assembly should be limited to twenty parts.

Question 3

Part 'd' was added to determine whether or not automatic assembly was being considered on the basis of increased output.

Question 4

Remained unchanged.

Question 5a and b

Functional check was added to this question. Part 'b' remained unaltered.

Question 6

"Less than 0.001 in." was thought to be clearer than "0 - 0.001 in." "Over 0.015 in." was changed to "greater than 0.015 in." for clarity. As the class intervals overlapped, the preamble was expanded for clarity.

Question 7

Remained unaltered.

Question 8

Remained unaltered.

Question 9

"No inspection" was removed from the question as it was not of any value. If there was no form of inspection, the question would not be answered. Functional check after assembly was included since the pilot survey indicated that this was necessary.

Question 10

Remained unaltered.

Request for Sample

The request for samples, where possible, was added after discussions between the Committee and the members present at the sixth Board Meeting. It was considered that samples would be beneficial to the analysis.

Metric Equivalents

It was decided not to include metric equivalents in the technical survey, since the majority of industry is unfamiliar with them at present. Also, the addition of the equivalents would have in no way simplified the survey.

Accompanying Letter

It was decided to send the survey to the Production Director of companies in preference to the Technical Director as in previous years, as this was thought to be more appropriate. It was appreciated that many of the companies selected would not have a Production Director, but it was felt that in most cases the survey would find its way to the most suitable person. The letter was designed to give the reader a broad outline of the design project in an attempt to stimulate interest and to encourage a good response to the survey.

4.0 Distribution of Questionnaire

The survey was circulated to 700 companies, the majority being selected at random from trade directories. The remainder were suggested by Mr. R. Iredale, Deputy Editor of Metalworking Production. The companies were selected to meet the following requirements:-

i) Representative of all areas in the United Kingdom.

ii) A minimum of 200 employees per company. This was an attempt to eliminate the very small companies which could not afford the investment of an automatic assembly machine. It was appreciated that this would not be true in all cases, but it was felt that this criterion would tend to make the analysis more realistic.

iii) Products were of a suitable size and type to make automatic assembly feasible ie. Shipbuilders and Boiler Makers etc. were excluded.

Despatch of Survey

The surveys were despatched between the 10th and 21st November, 1968. The letter and survey were accompanied by an envelope addressed to the Committee. It was decided not to send postage paid envelopes to the companies for two reasons.

i) the cost to the College

ii) the majority of firms would have their own franking service and therefore this would not be any further inducement to complete the survey.

All replies, whether letters or surveys, were acknowledged upon receipt.

A letter was sent to remind all those companies that had not replied six weeks after the despatch of the questionnaire (see Appendix II). The effect of this can be seen in fig. 1.

5.0 Discussion of Results

With regard to the comments in the Technical Survey Report 1968 (ref. 1), it was realised that a survey is only an indication of industrial requirements. To ensure that the results could be analysed on a statistical basis, a much greater number of survey returns would be required in order to obtain high confidence limits (ref. 4). For the above reasons, the results have been analysed on an intuitive basis.

5.1 Validity of Survey

All questionnaires returned were fully completed with no ambiguity in any of the answers. National Opinion Polls were contacted to determine whether the questions were presented in the correct manner so that they could be efficiently answered. The comments they made are as follows:-

1) Questions 1 and 6 had the class intervals incorrectly stated. It was thought that this ambiguity was offset by the wording of the preamble to both questions, which stated, "If the answer could fall in two ranges it should be placed in the smaller or the two."

2) Question 5b was leading, as the wording tended to suggest that automatic packing might be useful. From the replies, it would appear that this criticism was substantiated, as a higher percentage than was expected stated that they would like automatic packing. For further reading on validity of questionnaires, see refs. 2 and 3

5.2 Survey Returns

The frequency of survey returns was as shown in fig. 1. The effect of reminding industry of the questionnaire they had been sent is clearly shown. This indicates the value of sending the letter, since approximately a 30% increase of questionnaires was received. The final increase of replies in the 13th week was due to those firms who, upon receipt of the reminder letter, asked for and returned a questionnaire.

The reasons for not stamping the self addressed envelopes, which accompanied the questionnaire, as stated in 4.1 were clearly justified since 82% of the replies had been franked on company machines.

Most of the letters received outlined reasons why the questionnaire could not be completed by the recipients. This mainly occurred due to the lack of detailed information available in trade directories, on the manufacture and assembly of company products.

5.3 Results

From question 1, the results shown in fig. 2 indicated that 59% of the products considered for automatic assembly were of a size less than a 4 in (100 mm) cube; 88% were of a size less than a 10 in (250 mm) cube.

The distribution of the number of components per assembly, as shown in fig. 3, indicated that the most common range was 17 ~ 20. This made up 38% of all replies. The other four ranges were consistent at about 15%.

The answers to question 3a showed that 66% of companies use batch assembly (34% continuous assembly) for products thought suitable for automatic assembly. From question 3b, it was found that there was no common batch quantity for these products. It was therefore concluded that the batch quantity was at present dependent on individual company policy and would be liable to change with automatic assembly. Factors such as set up costs and machine utilization would become more important.

From questions 3c and 3d it was shown that 67% of companies were basing their requirements for automatic assembly on increased output.

The answers to question 4 (fig. 4) indicated that 86% of industry expected their product life to be between 4 and 10 years. From further questions the expected pay back period averaged 3.5 years.

Fig. 5 shows the operations which are most commonly found in assembly. Others used to a lesser extent include: lubricating, stencilling and cleaning.

The answers to question 6 (fig. 6) showed that 82% of assemblies require parts positioning to within 0.005 in (0.12 mm).

Fig. 7 indicates the planes of assembly used in industry of which the vertical plane is the most frequently used. Question 7b indicated that 40% of industry required automatic packing.

The results shown in fig. 8 indicated that 87% of components were assembled using four or less planes.

Fig. 9 shows that, for the range in question, the average time for assembly is related exponentially to the number of components in the product. For this to have occurred it is concluded that complexity must, in general, be a function of increased number of parts. If this was not the case the relationship would have been proportional. Types of inspection commonly used are shown in fig. 10.

Some comments in answer to question 10 are included below.

"Our feeling is that an assembly machine should be modular so that its components can be adapted to a variety of assemblies."

"Flexibility and reliability are two most important considerations, probably the best compromise in light engineering is to strike the right balance between costly feeding devices and manual assistance."

"One major problem to overcome would be to make the machine readily adaptable from one assembly to the other since most of our sub-assemblies have only a limited total life. This means the cost of the machine would possibly have to be written off against a number of assemblies."

"Where 6 and more components are being assembled the writer feels that a free floating pallet transfer system is necessary, with a buffer stop between each station to allow for slight differences in cycle. This system should not be condensed in any way and ample room should be left between stations so that in the event of a mechanical breakdown or modification to components an operator can be placed to manually perform the function required at that station."

6.0 Conclusions

The following conclusions have been drawn from the results of the Technical Survey.

1) The machine should be capable of assembling products which are less than 6 in (150 mm) cube. This would cover 73% of industrial requirements.

2) The machine should be capable of assembling products containing up to 20 parts. As there would be considerable variation in batch quantities, the machine should be made up of modules which could be easily interchanged.

3) Tooling should be as simple as possible to reduce the set up time on the machine.

4) The most common assembly operations required on the machine would be, locating, threaded fastening, push or force fits and functional check. These should be included in the basic assembly system.

5) The machine should be capable of positioning parts to an accuracy of 0.001 in (0.02 mm). This would cater for 87% of industrial requirements.

6) As the vertical plane is the most frequently used it was concluded that the machine should have the facility to turn the assembly over to enable parts to be positioned from underneath. Only 15% of industry required to assemble on planes A or C and B or D in their products, therefore the system for parts placing required only 2 axis movement (in the y and z directions).

7) When automatic assembly machines are used it was felt that the method of parts inspection would have to be rigorously controlled, prior to assembly, to ensure that stoppages do not occur due to faulty components.

6.1 Examination of Samples

From the critical examination of samples received from industry the following conclusions were made. In the majority of cases the components should undergo a rigorous value analysis before being considered for automatic assembly. Most of the assemblies were unnecessarily complicated and contained undesirable features which would make automatic assembly difficult. Therefore the machine should be designed on a modular basis which would enable manual operators to be used where complicated and therefore expensi automatic assembly techniques are required. Environmental conditio around the machine should be as pleasant as possible to aid the operator ie. minimum noise etc.

The 38% response to the questionnaire clearly showed the immense industrial interest in the field of automatic assembly. Many of those who were unable to complete the questionnaire showed interest in the design project and requested details of the final system.

6.2 Cranfield Versatile Assembly Machine

The table outlined below lists the basic manufacturing requirements and indicates the types of machine needed for production and assembly.

	Industrial Requirement	Machine Tools	Assembly Machines
a)	High Volume Production Long life product	Special purpose	Special purpose Multi-station
b)	High Volume Production Medium life product	Automatics	Unit Head Fixed index
c)	Medium Volume Production Short life or High variability product	Sequence controlled	Versatile Free Transfer
d)	Low volume production High variability product	Numerically controlled	Computer controlled

The machine designed at Cranfield to assemble a variety of contact blocks satisfies most of the requirements outlined in the report and would appear to fit case 'c' in the table for an assembly machine with limited versatility.

APPENDIX I

THE COLLEGE OF AERONAUTICS
(Proposed Cranfield Institute of Technology)
CRANFIELD, BEDFORD

TELEPHONE : CRANFIELD 321

NCIPAL: PROFESSOR A. J. MURPHY, C.B.E., M.Sc., F.I.M., F.R.Ae.S.
ISTRAR : LAURENCE WILSON, M.A.

DEPARTMENT OF PRODUCTION ENGINEERING

The Production Director

Dear Sir,

Questionnaire - Automatic Assembly Machine

An important feature of the post-graduate course in Production Technology is a group design project. The aim of this project is to provide each member with experience of working in a team of highly qualified engineers engaged on the design of machine/control systems. At the same time close contact is maintained with Industry and in addition engineers from many types of industry are invited to attend Project Board Meetings.

The subject of the design project for 1968/9 is an Automatic Assembly Machine and the team has been divided into committees to look into the various aspects of designing such a machine. One of the committees has to undertake a Technical Survey and it is our aim to obtain from Industry as much technical data as possible to aid the design of the machine. We hope that by your participation the resulting machine specification will encompass some of the assembly requirements of your product. This specification will be made available, on request, to those companies participating in the survey.

Mr. R. Iredale, deputy editor of Metalworking Production, who himself has a very keen interest in the subject of automatic assembly, has kindly agreed to co-operate with the study and has worked with the committee on the preparation of the Technical Survey Questionnaire. He will be studying the information obtained in more detail as part of a personal research project, the results of which will be published at a later date.

It would be appreciated if you would complete the enclosed questionnaire and if possible send a sample of your assembled product together with the components contained in it. Any information you supply will be treated confidentially. We would appreciate an early reply so that the committee can specify the basic machine configuration.

Yours faithfully,

G. G. LeHUNTE

Chairman - Technical Survey Committee

APPENDIX I (continued)

NAME: COMPANY:

POSITION: ADDRESS:

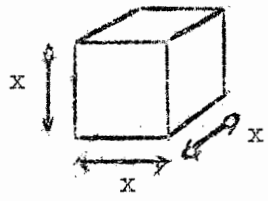
This questionnaire applies to the assembly and sub-assembly of products in your company.

Please answer all the following questions in relation to ONLY ONE of your most common assemblies or sub-assemblies with less than 20 parts, which you feel would benefit by Automatic Assembly.

Where you think it necessary follow with comments to aid your answers.

1. Indicate the size of your assembly or sub-assembly in the appropriate box. (If the answer could fall in two ranges it should be placed in the smaller of the two).

x in.cu.	less than 1 in.cu.	1 - 2 in.cu.	2 - 4 in.cu.	4 - 6 in.cu.	6 - 8 in.cu.	8 - 10 in.cu.	greater than 10 in.cu.
TICK							



(N.B. in.cu. NOT cu.in.)

2. What is the total number of parts in this product? Please tick appropriately.

No. of parts	1 - 4	5 - 8	9 - 12	13 - 16	17 - 20
TICK					

3. Quantities

	TICK
a) Do you use Batch Assembly	
or Continuous Assembly	
b) If Batch Assembly, state number of batches per year	
c) What is the present output per year of your product	
d) What is the expected output per year of your product	

4. Indicate the number of years you expect to assemble and sell this product. (Do not include service replacements which will be made after the assembly ceases to be a major production item.)

5a Tick those assembly operations given below that are carried out on this one product.

	TICK
Locating	
Riveting and Staking	
Threaded Fastening (Screws, Nuts, Bolts etc.)	
Adhesive Fastening (Araldite etc.)	
Push or Force Fits	
Heating (for expansion or setting etc.) ..	
Snap Fitting	
Soldering	
Welding	
Electrical Wiring	
Functional check	

Please state briefly any other operations carried out on your product during assembly.

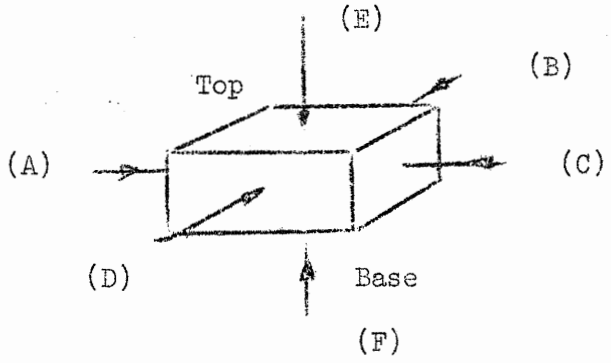
5b Would automatic packing be useful for your product

	TICK
Yes	
No	

6. Indicate the minimum locating tolerance on assembly of parts in this one product. (If the answer could fall in two ranges it should be placed in the smaller of the two).

	TICK
less than 0.001 in.	
0.001 in. - 0.003 in.	
0.003 in. - 0.005 in.	
0.005 in. - 0.010 in.	
0.010 in. - 0.015 in.	
greater than 0.015 in.	

7. Tick the planes used in the assembly of your product.



	TICK
A	
B	
C	
D	
E	
F	

8. How long does it take to assemble this one product

9. Tick the types of inspection carried out on this one product.

	TICK
Detailed inspection of each part before assembly	
Percentage inspection of each part before assembly	
Inspection during assembly	
Functional check during assembly	
Detailed inspection after assembly	
Percentage inspection after assembly	
Functional check after assembly	

Please state briefly any other form of inspection on your product.

10. Please give any further information which you think will help in the design of an automatic assembly machine and comment on where you think one would be of use in your particular industry.

It would be greatly appreciated if you could send a sample with this questionnaire, of the <u>one</u> sub-assembly or assembly upon which you have answered the questions.

APPENDIX II

THE COLLEGE OF AERONAUTICS
(Proposed Cranfield Institute of Technology)
CRANFIELD, BEDFORD

TELEPHONE : CRANFIELD 321

PRINCIPAL: PROFESSOR A. J. MURPHY, C.B.E., M.Sc., F.I.M., F.R.Ae.S.
REGISTRAR : LAURENCE WILSON, M.A.

Ref.: GGLeH/VAR

15th January, 1969.

Dear Sir,

Several weeks ago we sent you a questionnaire on automatic assembly. This is the subject of a design project which is being carried out in the Production Engineering Department at Cranfield.

The response from Industry to date has been very encouraging and we are wondering if you would still like to participate in this project by completing and returning the questionnaire. If the questionnaire has been mislaid please contact us for another. Perhaps you would send a sample of an assembly or sub-assembly which you carry out, with less than 20 parts and less than 10 in.cu., which you feel would benefit by automatic assembly.

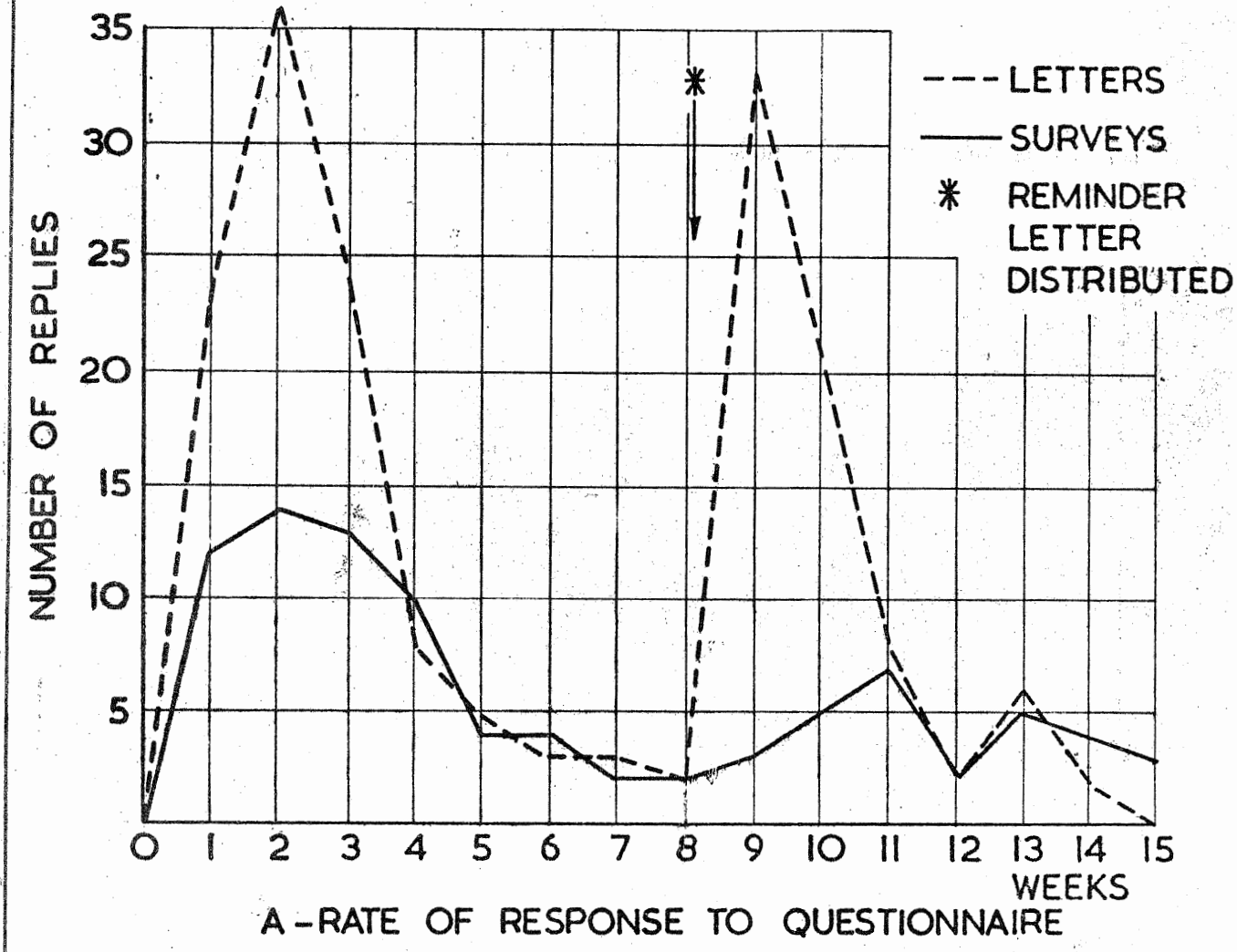
The replies have not yet been analysed so we are hoping that you would still like to aid the project.

Yours faithfully,

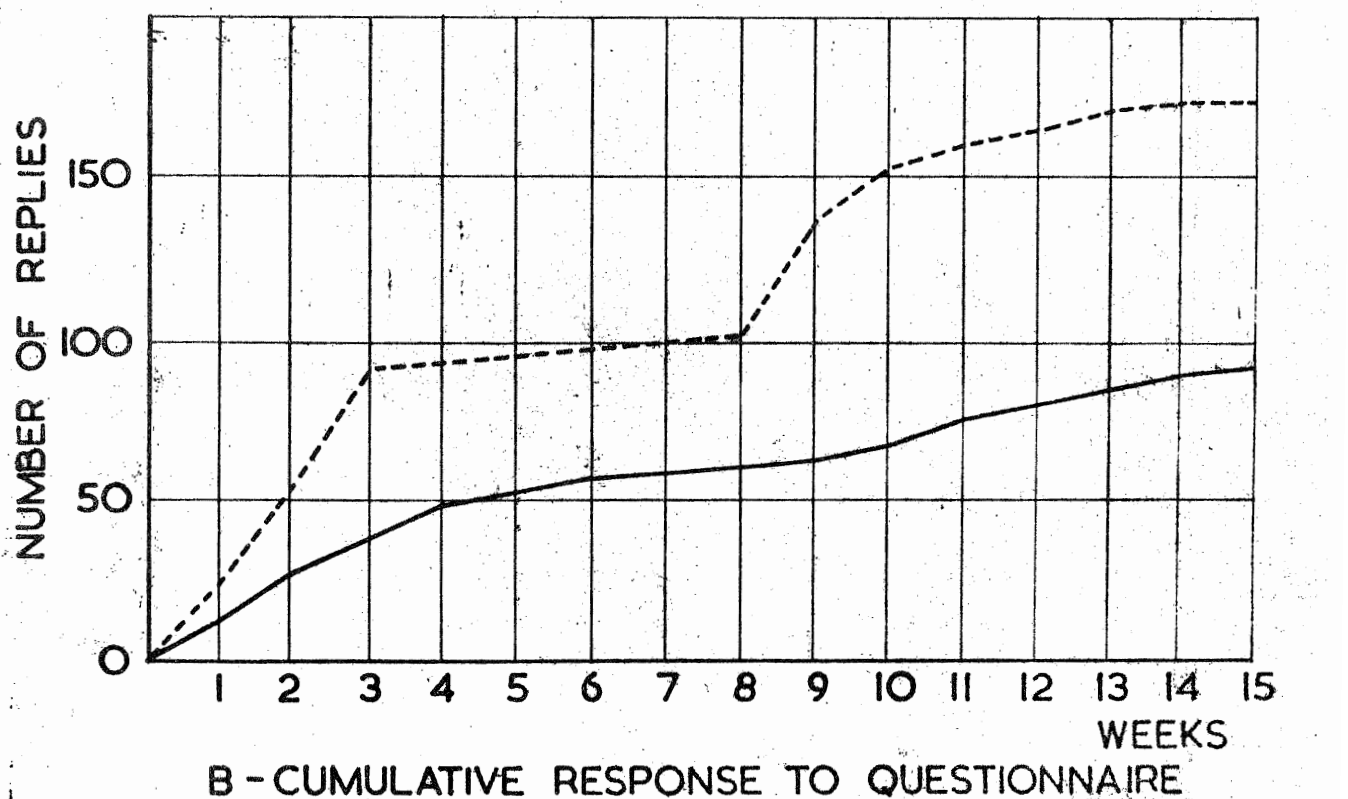
G. G. LeHUNTE
Chairman - Technical Survey Committee
Production Engineering Department

8.0 References

1.	-	Report of Technical Survey Committee, Design Project 1968, CoA Memo 155.
2.	Professor Moser	Survey Methods on Social Investigation, (Heinnemann).
3.	Stacy and Wilson	Industrial Marketing Research (Hutchinson).
4.	Hanson, Hurwitz, Madow	Sample Survey Methods and Theory, Volume 1, (Wiley).



A - RATE OF RESPONSE TO QUESTIONNAIRE



B - CUMULATIVE RESPONSE TO QUESTIONNAIRE

FIG. I.

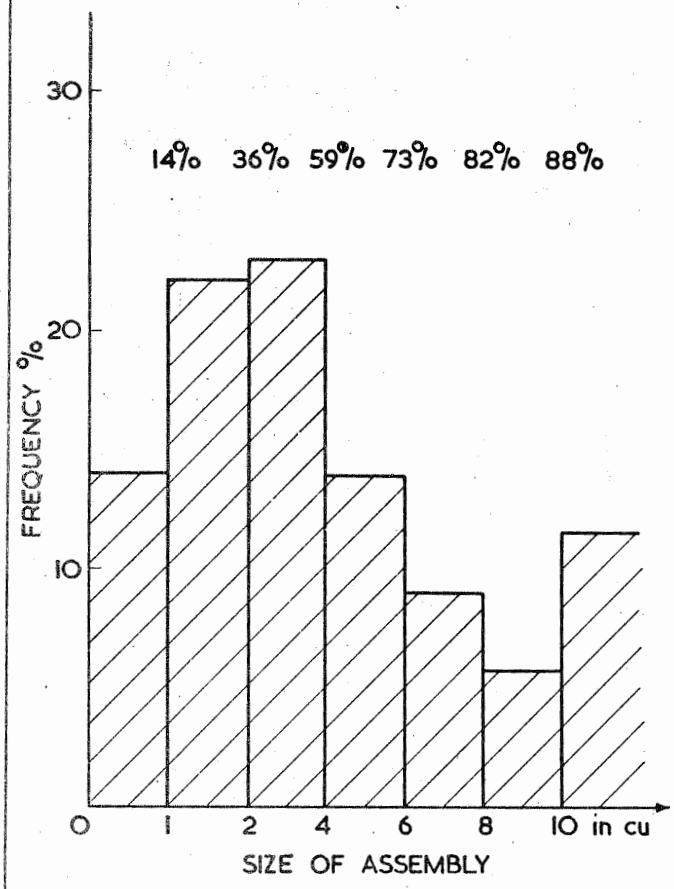


FIG.2.

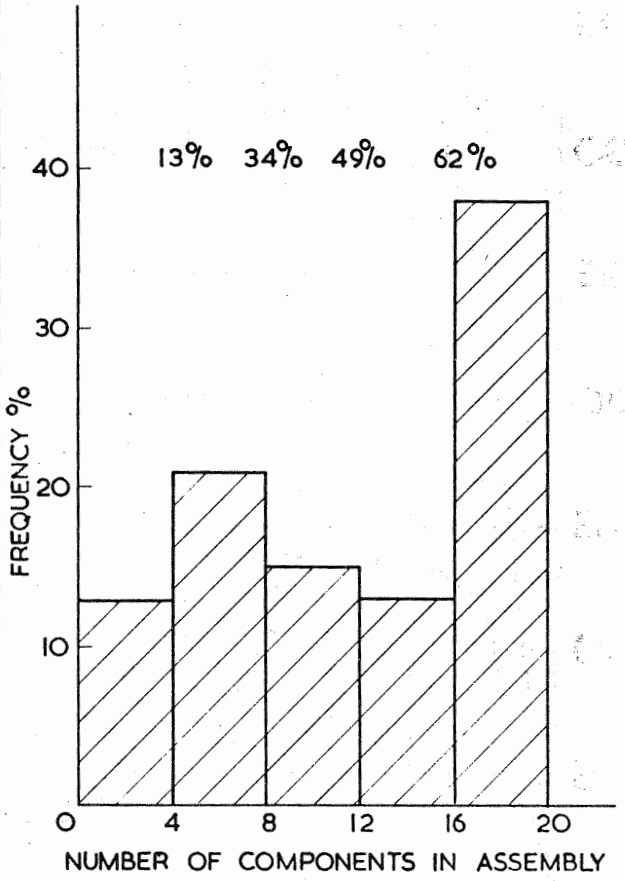


FIG.3.

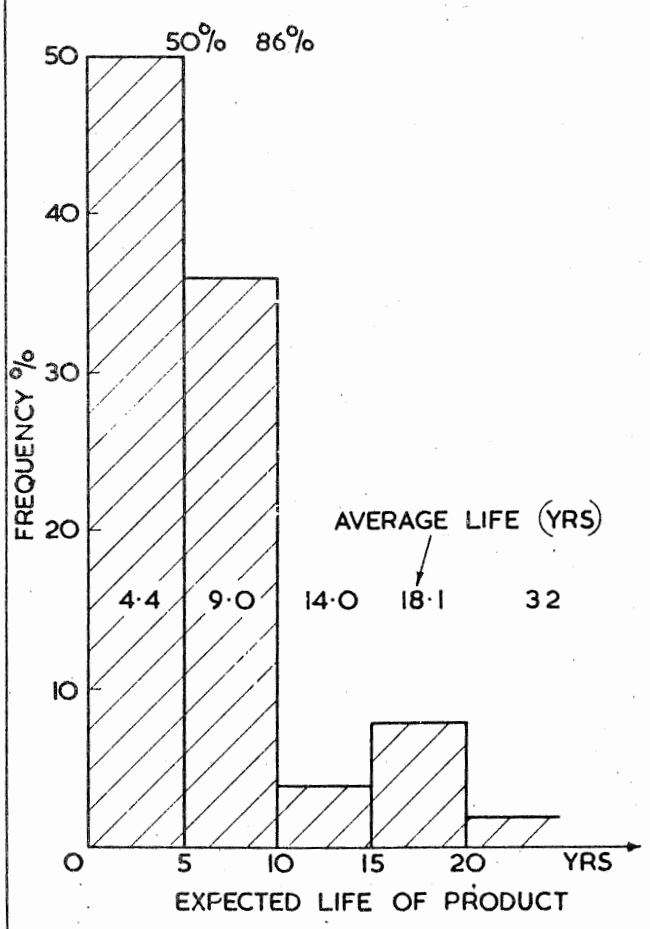


FIG.4.

FIG.2. DISTRIBUTION OF ASSEMBLY SIZES. QUESTION .1.

FIG.3. DISTRIBUTION OF COMPONENT QUANTITIES. QUESTION .2.

FIG.4. DISTRIBUTION OF LIFE OF PRODUCT. QUESTION .4.

ASSEMBLY OPERATIONS	FREQUENCY %
LOCATING	97
FUNCTIONAL CHECK	62
PUSH OR FORCE FIT	55
THREADED FASTENING	52
RIVETING	44
SNAP FIT	33
ELECTRICAL WIRING	13
WELDING	12
SOLDERING	11
HEATING (FOR EXPANSION OR SETTING)	8
ADHESIVE FASTENING	8

FIG.5.

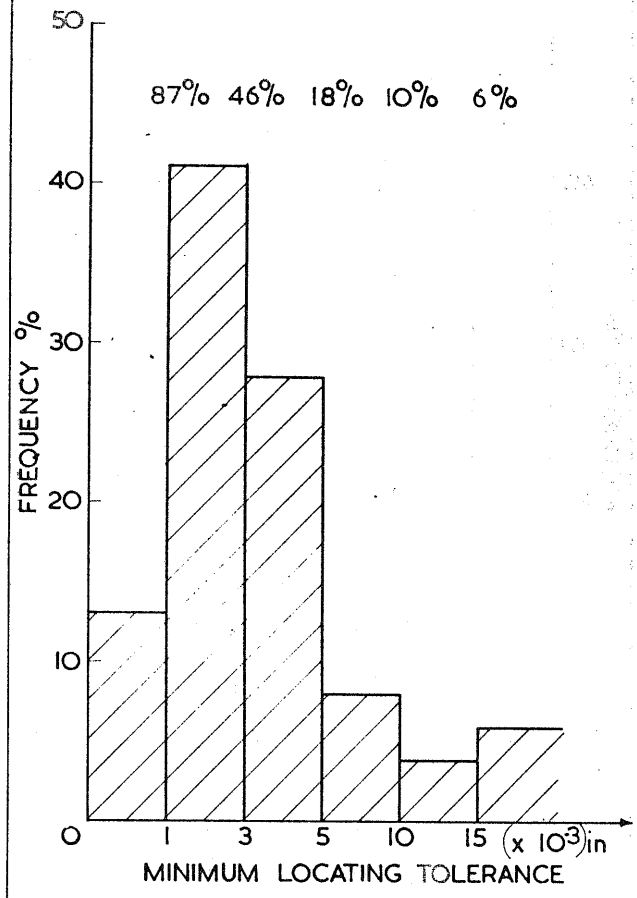


FIG.6.

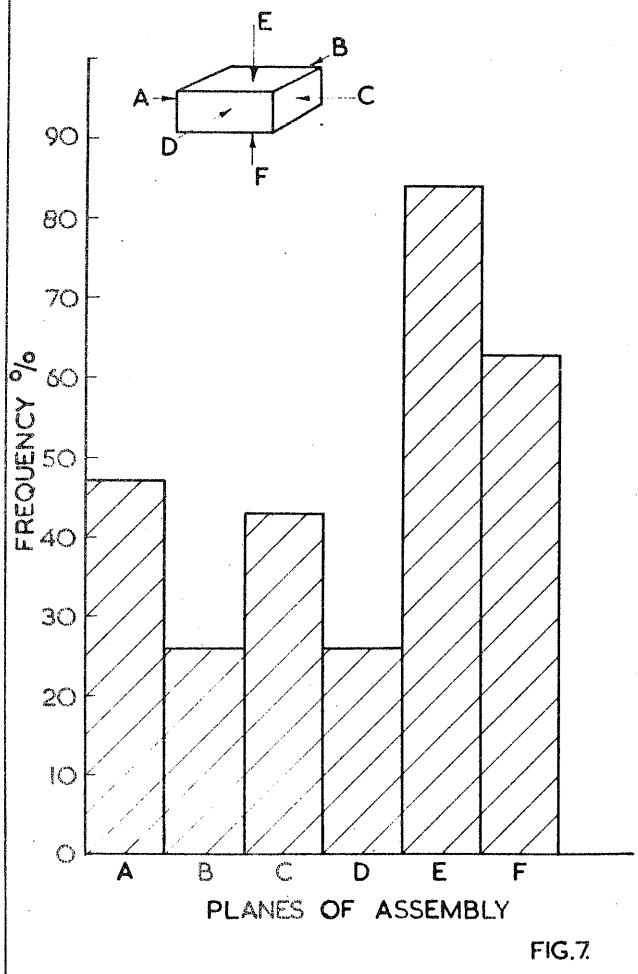


FIG.7

FIG. 5.- ASSEMBLY OPERATIONS QUESTION .5.

FIG. 6 - DISTRIBUTION OF LOCATING TOLERANCES QUESTION .6.

FIG. 7. - DISTRIBUTION OF PLANES OF ASSEMBLY QUESTION .7.

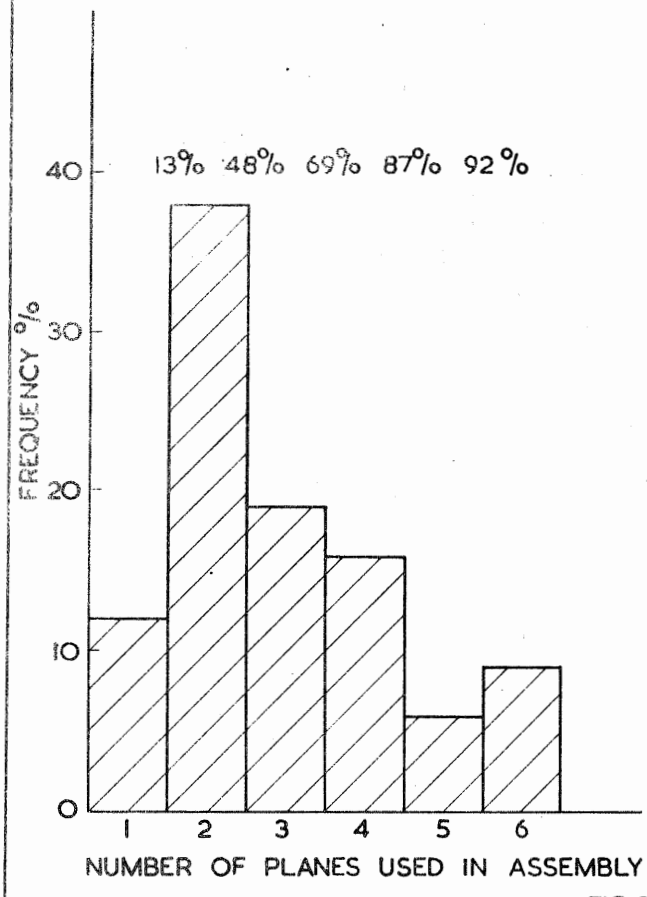


FIG.8.

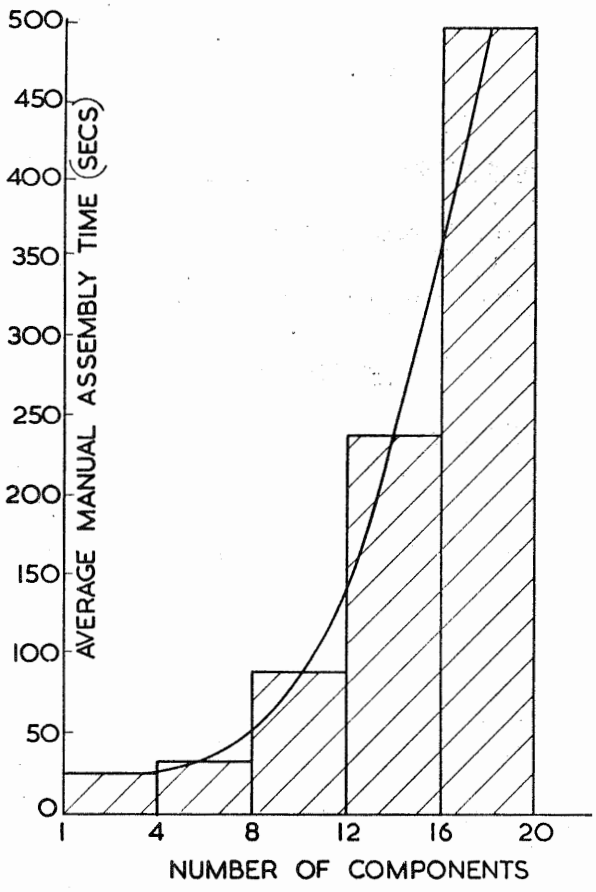


FIG.9

	ASSEMBLY STAGE		
INSPECTION	BEFORE %	DURING %	AFTER %
DETAILED	12	36	33
PERCENTAGE	80	–	38
FUNCTIONAL	–	28	77

FIG.IO.

FIG. 8.-NUMBER OF PLANES USED IN ASSEMBLY. QUESTION .7.

FIG.9.-ASSEMBLY TIME v NUMBER OF COMPONENTS. QUESTION .8.

FIG.IO. - TYPES OF INSPECTION. QUESTION .9.