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# PROPOSED
# DIGITAL COMPUTER INSTALLATION
# FOR THE
# DESIGN DEPARTMENT

ISSUED BY (Lom/CLJ
(Lom/LJS/LG

To. Hs.

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# PROPOSED DIGITAL COMPUTOR INSTALLATION
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# PART I

## RECOMMENDATIONS

We wish to recommend that :-

1) We should install an electromechanical calculator and ancilliary equipment to carry out the calculation of the ordinates of all compressor blade details and to do most of the laborious work of the Stress Office.

2) We should hire sufficient equipment from I.B.M. to cover the above requirements at the following cost :-

| | |
|---|---|
| Initial outlay(excluding cost of providing office space) | £470 - 0 - 0 |
| Monthly outlay(rent plus cards) | £286 - 17 - 0 |

3) After operating this equipment for three years we should review the position as by that time it is possible that Powers-Samas will have developed an electronic calculator which will do more work for about the same cost as present day electromechanical calculators; on the other hand I.B.M. may then also have improvements to offer.

## PART II

## CONCLUSIONS

1. The calculation of the coordinates and further the printing of them onto a master detail drawing, of blade section profiles by a digital computor installation is a perfectly practical proposition.

2. An electromechanical calculator would have sufficient capacity and speed to do the blade detail job and, in fact, blade details would only occupy the calculator for a comparatively small percentage of its time.

3. We find that the calculator could also make a considerable and extremely valuable contribution, probably even greater than that which it could to blade detailing, to Stress Office and Performance work.

4. In addition to the time saved, and bearing in mind the greatly increased quantity and standard of work that would be achieved in all these fields, the possible savings in manpower would be more than equivalent to the rental of the installation.

5. We consider that I.B.M. is the only company operating in this country that can fully meet our requirements at the present time.

6. After operating the equipment for three years the position should be reviewed and consideration given to the advances made by the various companies concerned with the manufacture of computing machines.

7. The I.B.M. machines that we would need are a calculator, numeric key punch, numeric verifier, collator, reproducer, sorter and tabulator. The rental for all these units would be £276. 17. per month and the initial cost of extra control panels and equipment for the sorter would be £368. 13. In addition we would require filing cabinets and a fairly large cupboard for storing the control panels.

8. The installation could be successfully operated by a supervisor, who would of necessity be an experienced mathematician, and three other personnel who should be of the standard of the present blade detail section.

9. To house the machine units and the personnel operating them a room measuring 17 ft by 25 ft would be required.

## PART III

## DISCUSSION

At a meeting held by E on 18.11.52. to discuss compressor blade detailing Lom suggested that all the dimensions required to manufacture the aerofoil portions of axial compressor blades could be calculated by an electronic computor and it was agreed that this proposal should be investigated.

See minutes of the meeting ref. Kby. 2/B. 20.11.52. and also Lom. 1/MPB. 17.12.52. and Lom/LJS/RBL. 2/SH. 16.12.52.

When this proposal was investigated it was found that it was perfectly practical and in fact could be carried out with a considerable saving in time and manpower on an electromechanical calculator. This is fortunate because electronic calculators of the required type are not yet readily available in this country. It was also found that as several different methods of blade design are in use a machine of some flexibility would be required and that even with electromechanical operation the machine would not be occupied full time on blade detailing. We therefore investigated the possibility of also using the machine for stress and performance calculations and we found that it could make an extremely valuable contribution to this work, not only by saving time on routine jobs but also by allowing us to investigate complex problems in increased detail and even to tackle problems which by present methods would involve prohibitive labour. Further it was found that in addition to the time saved and bearing in mind the greatly increased quantity and standard of work passing through the Design Department, the possible saving in manpower would be equivalent to the rental of the machine including servicing charges.

We have considered the products of various companies in the field of digital computors. It was soon apparent, however, that for our type of work the choice rested between I.B.M. and Powers-Samas. The advantages of these two types are as follows :-

(i) CHECKING

The method that has been used by Powers-Samas for a number of years of checking cards by punching overlapping circular holes is quite fool-proof, however, I.B.M. have recently introduced a system by which a single notch is marked in a card when it is checked on the verifier and this notch will not be made if the operator has omitted to verify any column on the card which should be punched. We consider this last system to be as fool-proof as that used by Powers-Samas.

(ii) FLEXIBILITY

The I.B.M. machines are controlled by quickly detachable plug boards (i.e. control panels) which are wired up with lengths of flex that are plugged in by hand. With this system a number of these boards would be kept permanently wired to follow the programmes of various routine jobs that would be done on the machine. From time to time we will want to alter the boards already wired up to cater for modifications and/or extensions to these routine calculations. Furthermore there are a number of jobs, which involve prohibitive labour by normal methods, that we will want to do on the machine, but until we have attempted to do them by various methods on the calculator we will not be in a position to decide which method is preferable. Also there is a considerable number of useful jobs, such as compiling stress and deflection tables or curves for tubes under various end conditions, which once done would probably never have to be repeated. For all these reasons it is clear that we require a system of control boards, such as I.B.M's, that can be made up or changed by the operators or supervisor.

Powers-Samas machines are similar in principle to those of I.B.M. but the control boxes, which contain a mechanical system of rods or a set of soldered electrical connections, are rigidly manufactured to the customers requirements for any one job by the nearest Powers-Samas service depot ( in our case Birmingham). These boards cannot be altered or made up by the personnel operating the machine.

This difference between the products of the two companies applies to the auxiliary machines as well as to the main calculator and we are convinced that, despite the rapid service that Powers-Samas have given to our Accounts Department in the past, this process would be too inconvenient for our type of work. Delays would arise in two ways.

Firstly, our type of work develops far more rapidly than that of an accounts department, both owing to changes in design (e.g. of blades) and, as stated above, to the fact that we frequently find that mathematical methods introduced for one type of problem can be extended and applied to new problems. In both these cases minor modifications to control panels could be made to deal with the changes, and a certain amount of experimenting might be required to incorporate the improvements in the best way.

Secondly, on the auxiliary machines we shall frequently need to carry out minor operations which are not standardised. These can be carried out on an I.B.M. machine by small temporary rearrangements of the control panel or in many cases even more simply by the use of selector switches. As all the Powers-Samas auxiliary machines are mechanical these adjustments are less convenient on them.

In addition, it is probable that with the I.B.M. system we could operate with a total of 16 control panels for the calculator and that with these we would be able to tackle all the blade detail, stress, and performance work described later on in this report. This would only be possible because we would not have to keep the boards wired up for the less frequent jobs but would instead keep a filed system of proved wiring diagrams from which the boards could be quickly wired by the operator. For such frequent and routine work as blade details, disc stressing, and vibration problems we would keep the boards permanently wired up. With the Powers-Samas system, we would certainly not be able to cover the same field with anything like such a small number of control panels.

The above remarks should not be taken to imply that we do not appreciate the very real advantages of the Powers-Samas system for carrying out routine calculations in a standardised form, such as are encountered in an accounts department, with great reliability.

(iii) MANUFACTURE AND SUPPLY

I.B.M. are an American company but they have a factory in Scotland which is just getting into production and they would be able to supply the units that we require in about six months from the receipt of an order, owing to the fact that they did not book orders for the full capacity of this factory before they were certain when it would be ready. It is possible that there would be a slight improvement in this delivery if we obtained priority through the Ministry of Supply.

Powers-Samas are a British owned company - part of the Vickers Group - but they have factories abroad. However, they have at present no standard machine or machines made in this country which will even perform all the basic arithmetical operations. This factor coupled with the lack of flexibility of control that all Powers-Samas machines suffer from means that they would in no way meet our requirements. They have suggested to us that they would attempt to adapt one of their electromechanical P.C.E. calculators, made in France by a subsidiary company, to do as many as possible of the calculations that we require. On consideration of the fact that all our jobs would first have to be programmed for their machines, the additions to the machine necessary decided upon, and then the necessary extras designed and built into the P.C.E. we consider that there will be little to choose on delivery dates either way. In addition it must be remembered that it is extremely doubtful even then that we would have a machine to meet all our requirements and it would certainly not have the flexibility that we require.

Powers-Samas are aware that this proposal would only be acceptable as a temporary measure and they only made it because in 2½ to 3 years time they hope to produce an electronic machine which would have a large capacity, be simple to programme and would only cost about the same as present day mechanical calculators.

(iv) SALES AND SERVICE

Our Accounts Department buy nearly all their machines from Power-Samas and pay a servicing charge in addition. Occasionally they rent machines for short periods in which case the rent includes the service charge. To maintain all these machines there are two resident Powers-Samas service engineers.

I.B.M. do not sell their equipment except for plug boards, cards and other small accessories and all the units are rented at an inclusive charge. The renting contract runs for a minimum of twelve months and may be terminated then or at the end of any month thereafter by giving three months notice.

The nearest I.B.M. representative is at Birmingham at present although they may take charge of the American built I.B.M. equipment at the R.C.A.F. base at Langar near Nottingham. The contract would require that we paid the travelling expenses of their engineers coming to carry out maintainance and repair from one of these places. De Havillands have an I.B.M. installation and have had runs of up to three months with no trouble whatever, and we therefore do not think that the advantage of having resident engineers available if we used Powers-Samas machines would be very great, especially as our main calculator, which would be of French design and manufacture, would have nothing in common with the types of machine which we have at present installed in the Accounts Department, except the cards and the method of reading them.

(v) LITERATURE

I.B.M. have published a valuable set of manuals on the programming and principles of operation of their machines. They have also published a considerable number of technical papers on the programming of the machines for various mathematical and engineering problems, of which they have had a vast amount of experience in America. I.B.M. have been able to do this as, for a number of years, they employed a large research staff whose job it is to investigate the possibilities of their machines for scientific and engineering usage. They have further promoted this side of their work by holding annual Forums, the proceedings of which are published, at which leading engineers and research staff from industry and the Universities are invited to contribute the knowledge they have gained from experience on the machines. We would derive considerable benefit from this literature if we were operating I.B.M. machines.

On the other hand, if we were to accept the proposal made to us by Powers-Samas we would be operating a machine of which their British engineers and research staff have had comparatively little experience, and further, we would be using it for types of computation work of which they have had comparatively no great experience and to which they have made no contribution by published literature.

On careful consideration of the merits of both systems we strongly recommend that we rent an I.B.M. calculating machine with all necessary auxiliary units and that in three years time we again review the situation by considering the advances made by both companies.

During a visit to I.B.M's headquarters in London we were given an opportunity of meeting Dr Barnett, a Research Fellow of London University who has a University grant to enable him to rent time on the calculating machine installed in I.B.M's Service Bureau in London. Dr Barnett was trained in the use and programming of I.B.M. machines for scientific and engineering purposes at their Watson Laboratory in America. We discussed with Dr Barnett in some detail the types of work which we wish to apply to the machine and to some extent considered the programming necessary for the Blade Detail job. During this discussion Dr Barnett very kindly offered to give his time for a fortnight training a member of our staff to programme jobs for the machine. The most suitable trainee would of course be the eventual supervisor of the Computing Section who would be an experienced mathematician. I.B.M's fully support this offer and we consider it to be one of great value to us and recommend that it be accepted.

# PART IV

## DISCUSSION OF BLADE DETAILS

As stated in the discussion this was the first problem considered and it was found that it could be dealt with satisfactorily and that the machine would only be occupied part time on this job.

The types and capacities of calculating and ancilliary machines required has been considered in some detail for this particular job and it was found that for all types of compressor blades a table of the coordinates of any number of section profiles with reference to datum axes could be conveniently produced by the machine. This would apply to C4 and C5 aerofoil section of circular and parabolic arcs and also to lenticular blading. For production purposes sections would still have to be drawn out, but the work of the blade detail section would be appreciably cut and the speed of this work would be considerably increased.

We have also considered the possibility of obtaining the blade sections directly as photographs on glass plates by a different type of machine. However machines of this type (known as analogue machines), which would carry out the operations to the same accuracy as a good draughtsman, are not yet available and, as far as we can find out, are not likely to be for some years.

FN had proposed that transparent master sections should be drawn by the blade detail department and these would be the official standard for all manufacturing processes, and would carry no dimensions. There are a number of objections to this which our proposals will overcome and we have discussed these with FN and TB/HHS/EJB of the Tool Office and we are now in agreement as to what the best procedure is.

The main objections were as follows :-

(a) Dimensions are required for determining the mid section of a ruled blade for inspection purposes and for extrapolated sections beyond the end of the working blade form for die-sinking purposes.

(b) Even the best drawing, without mechanical aids, is not quite accurate enough. Errors equivalent to more than $\pm$.010 ins on a 10:1 drawing (i.e., $\pm$.001 ins full size) can arise. This is an appreciable fraction of the required limit of $\pm$.0025 ins and is liable to take the form of slight ripples in the surface which can be exaggerated at the extrapolated sections mentioned above if the errors at the two basic sections are of opposite sign. At present the Tool Office redraw the sections on transparent material with the aid of a micrometer machine operating on two axes at right angles to a much higher standard of accuracy and smooth out the irregularities in the profile. If FN's proposal were adopted in its original form these smoothing errors would not be eliminated and we should produce an inferior article.

The Tool Office drafting machine requires ordinates on rectangular axes which they are receiving on the present detailed drawings and which we intend the machine to reproduce to higher accuracy so that we will no longer start the chain of operations with a process which is of lower accuracy than the subsequent tooling and die-sinking operations.

Photographs on glass of the Tool Office master sheets are used in the manufacturing and inspection processes. These include photographs scaled up by the required contraction allowance for the forging dies.

It must be admitted that by this procedure we are still left with one drawing operation which is slightly slower than ordinary drawing, but there is no way at present to eliminate this.

The procedure for calculating the ordinates for aerofoil section blades would be to prepare a standard pack of cards on the Reproducer carrying the ordinates of a C4 or C5 section for a standard thickness of 10% and hand punch a few cards with the thickness, chord, camber angle and stagger for the basic sections. These cards would be fed into the calculator ahead of the standard pack in order to store the information for operations on the standard pack. At a later stage cards from a further standard pack carrying sines and cosines would be interspersed in the required order on the Collator and the mixed pack returned to the calculator for further operations. A further operation on the Reproducer would also be required because of the limited number of columns on the cards and to separate the ordinates of the upper and lower surfaces of the blade.

It will be seen that although the above calculation is fairly complicated very little hand punching of cards is required which makes for speed and accuracy.

It will be possible for the I.B.M. tabulator to type the results of the above calculations of ordinates directly onto a standard drawing sheet similar to the present sheets for gear detail drawings. This standard sheet would carry a purely diagrammatic outline of the blade section to illustrate how the ordinates are specified. Since it would not be convenient to use a sheet larger than our size IV (19 ins by 26 ins) on the tabulating machine it will probably be desirable to put the remaining blade detail dimensions such as those of the blade root on a separate sheet. This ordinary drawing work could then be carried out in parallel with the computation, and the two sheets would constitute the Master Detail Drawing.

Experiments have been carried out to obtain satisfactory printing on tracing paper from an I.B.M. tabulator so that good blueprints can be produced. After some initial set-backs this problem has been solved.

## PART V

## DISCUSSION OF STRESS OFFICE WORK

There are a number of problems that are a feature of Stress Office work and are of a purely routine nature - the most outstanding of these being the stressing of discs.

Disc stressing, although it is a routine job does take up a considerable amount of the time of personnel who are qualified to do work of a more advanced nature. The method of disc stressing in current use is ideally suited for computation on an I.B.M. machine. In addition to relieving a number of personnel of this routine calculation and so increasing the speed with which other non-routine jobs can be tackled in the Stress Office, the machine is capable of stressing discs at an enormously increased rate than at present possible. We have also developed a method (Stress Office Data Sheet 31) for finding the stresses and deflections in a flat plate of non-uniform thickness which is similar to that used for stressing discs and could utilise the same programme with additional steps. This method is much more laborious when done by hand than that for rotating discs and for this reason rarely used at present.

Another routine job which frequently occurs and which could be done in the machine is that of the stresses and deflections of tubes under various end conditions. It has been suggested that the best way to deal with this and other similar jobs would be to calculate a set of tables which could be published as data sheets or as graphs.

The machine could also make an extremely valuable contribution to Stress Office vibration work. A lot of modern frequency computation is performed by matrix iterative methods; this is especially true when the system to be investigated possesses a comparatively large number of degrees of freedom.

Quite recently we have investigated the frequencies and modes of vibration of the Avon Mark I production engine and obtained a remarkable agreement between our calculated frequencies and relative amplitudes and those measured on actual engines on the Test Beds. It was claimed in the published report of that investigation that in view of the proven accuracy of the method the cause and cure of a rough engine could be determined analytically in a comparative short time. The method of investigation used was a matrix iterative one. Unfortunately, when the work is done with the sole aid of a desk calculating machine, it takes approximately two months to determine the modes and to find the effect of altering a limited number of thicknesses, and in fact, it would rarely be the case with present methods that we would have sufficient time to investigate fully the effect of changing stiffnesses. In addition, as is natural in an engineering firm, very few of our staff are qualified mathematicians and they therefore do not possess a knowledge of matrices. With the I.B.M. machine we would be able to investigate the effect of changing stiffnesses on a rough engine in a remarkably short time, provided that the supervisor of the section, who would also programme jobs for the machine possessed a knowledge of matrices and was familiar with vibration work. We could possibly save a considerable amount of time on development work on future engines by this type of investigation.

In addition, the machine could make a considerable contribution, both in saving time and by releasing some of our personnel for other work, by being used for our more routine vibration work such as flap frequencies and torsional vibrations of blades, and the critical or whirling speeds of rotors in rigid or flexible bearings. We have recently worked out a matrix adaptation of the Prohl Method for determining natural frequencies which would be ideal for rapid computation on the machine and which could be applied successfully to these problems.

There are a number of problems that cannot be solved accurately at present, due to the prohibitive time that would be entailed. For instance, one of these problems which is of frequent occurrence, is the accurate calculation of the rate and stressing of a conical disc. None of the methods that are conveniently done by hand give even reasonably accurate results, and it is thus necessary to have model conical discs made and the rates determined by rig tests. This has in the past caused considerable delay to a number of Stress Office investigations.

It is probable that an accurate method of determining the rate of a cone would be to split the cone up into a large number of small rings with a system of forces and moments on each elemental ring. If the method were to be reasonably accurate it would entail the solution of at least thirty or forty simultaneous equations. These would take far too long to solve by hand, but could be successfully solved by a machine in a remarkably short time.

An alternative method would be to solve the differential equation for the stresses and deflections of the cone for a smaller number of steps and proceed by an elaboration and combination of the methods for flat plates and discs. This would involve the solution of a quintic equation by some method of successive approximation.

It should be noted that solutions of equations of a similar order are required in the investigation of control stability problems. Such an investigation has recently been carried out by the Stress Office on the RB.82 system and a standard mechanical method of find all the roots, real or complex of equations of fifth or even higher orders would be of great value in assessing the effects of changes to the various engine parameters much more rapidly than can be done at present.

We are convinced that the contribution that a calculating machine could make to Stress Office work is at least as great as that to be gained on blade details, the work which we first considered for application to the machine.

# PART VI

## MACHINE UNITS REQUIRED

The calculating machine and auxiliary units that would be required to cover the range of computation work indicated in section VIII of this report are as follows :-

### (i) 602-A CALCULATING PUNCH

As stated earlier, we found that an electronic calculator is not required to meet our initial programme of Blade Detail, Stress Work and Performance Work and we consider that I.B.M's electromechanical 602-A Calculator possesses the requisite capacity. We would, however, require all the extra optional storage units, counters, and selectors for this machine.

In the type 602-A any number of columns up to the capacity of the card can be read as factors of a calculation. Additional fixed factors can be entered from a digit emitter. Factors can also be developed through calculation and held for use in further calculations. Capacity is available for holding as many as 102 digits. Original factors and intermediate results can be cleared from the machine at will, to provide space for additional calculated factors or results. All results are punched from two 12 position units which can be used repeatedly up to the capacity of the card.

The Type 602-A operates at a speed of 12,000 cycles per hour. The number of cycles required for the calculation of a card depends upon the size of factors and type of problem.

The control and flexibility of the machine have been fully discussed in section III of this report.

### (ii) TYPE 513 REPRODUCING PUNCH

This machine is used for reproducing punched sets of table look-up cards and reproducing part or all of the cards calculated on the 602-A. The model that we require is equipped with 45 columns of comparing and 10 positions of double punch blank column detection.

This machine is essential for the rapid and efficient running of the whole installation.

(iii) TYPE 077 COLLATOR AND TYPE 080 MODEL 2 SORTER

Our main use for this machine will be to look-up tables of functions such as sines and cosines. It operates by inserting a card carrying the value of the function required ahead of each card on which a calculation is being carried out. The mixed pack of cards would then be taken back to the main calculator for further operations involving the function in question.

De Havillands have not got a collator and have not yet done any calculations involving looking up tables, but they suggested that if they did they could do it on their medium speed sorter (450 cards per minute). This proposal has two disadvantages. Firstly a sorter can only sort on one column of the cards at a time so that three or four runs through the sorter would be required to read the tables to the required number of significant figures. Secondly, with the sorter, the cards from the table pack which are not required cannot be removed and they would all have to pass through the main calculator which would waste time on the one unit we cannot afford to.

The collator, on the other hand, sorts on the required number of columns at once and De Havillands seem to have been under a misapprehension as to its speed which they thought was 100 to 150 cards per minute while it actually runs at 240 to 480 cards per minute, the maximum speed occurring when cards are chosen alternatively from each pack. The collator will also separate the cards from the table which are not required.

The collator can also be used to separate the table cards from the others at the end of the operation and reinsert them in the table, but for most of its operations it is essential that the cards should be in the correct order. This will normally be the case but a sorter will still be required to deal with packs of cards which get out of order and for various other jobs. Accordingly, for our purposes the lowest speed sorter (250 cards per minute) will be adequate and will entail £6 per month less rental than a medium speed sorter.

(iv) TABULATOR (TYPE 420 ACCOUNTING MACHINE)

This is the machine on which we propose to print the table of ordinates directly on to the blade detail drawing. For a simple ruled blade this would take two minutes actual running plus the setting up time and for non-ruled blades one to two minutes per section according to the number of ordinates. It will therefore only be running for a very short total time on this job. For other jobs, such as recording the results of disc stressing calculations, the running time would only be a few seconds, and while we should use it to reduce the chance of copying errors it must be regarded as a luxury for this latter type of work.

As this machine does not cost a great deal less than the calculator itself it is clear that it cannot be justified on its own merits and its value must be considered in relation to the whole installation particularly for the blade detailing job, which is, of course, the primary purpose of the proposed installation. For this job we regard the Tabulator as practically essential because the additional time taken and the risk of errors in copying punched ordinates from the cards on to the drawing would reduce the savings in time and manpower very seriously.

Tabulators are made in a large range of sizes and speeds and even the smallest are capable of carrying out simple arithmetical operations as well as printing the results, and we have considered in what way this capacity would be of use to us. In view of the above remarks it is evident that the slowest speed Tabulator would be adequate and that no special features should be fitted which will not save time on the other machines on the blade detail job. The only operation of this type which we think worth while is to programme the tabulator to calculate the mean ordinates of the centre section of a ruled blade in addition to the datum sections which have been worked out on the main calculator. We find that this can be done on the smallest size of tabulator and the cost of this is included in the figures quoted elsewhere. This small amount of calculating capacity would be of use in some other jobs.

We have investigated the possibilities of using the tabulator for other jobs which would require very little time on the other machines and there are a few jobs where this would be of use. One of these would be tabulating the ordinates including those of intermediate sections, of ruled turbine blades and nozzle guide vane blades, when the end sections have been determined by the present methods. Another possible job arises in the inspection of involute form teeth for ring and plug gauges for involute splines. The Tool Office require ordinates and the possible saving for this job are discussed in section VIII of this report.

De Havilland Propellers have not got a tabulator as, in their present work, they would have even less use for it than in our Stress Office jobs and they have not yet considered using their machines for detailing propeller blades or for any job requiring a large number of final results.

## (v) TYPE 116 NUMERIC KEY PUNCH & TYPE 155 NUMERIC VERIFIER

The Key Punch is used to enter data on to the cards that are needed for calculation purposes. The Verifier, as its name implies checks this operation. I.B.M's have recently incorporated what we consider to be a foolproof checking system on this machine.

The weight dimensions, and power consumption of these units are contained in the following table

| Machine | Weight (lbs.) | Dimensions (ins.) | | | Power Consumption in amperes at 230 volts |
|---|---|---|---|---|---|
| | | Length | Width | Height | |
| Key punch | 175 | 42 | 29 | 38 | 0.8 |
| Verifier | 175 | 42 | 29 | 38 | 1.2 |
| Sorter | 425 | 61 | 16 | 46 | 2.5 |
| Collator | 758 | 50 | 19½ | 51½ | 6.9 |
| Reproducer | 800 | 46 | 24 | 48½ | 6.1 |
| Calculator | 930 | 56 | 28 | 42 | 3.0 |
| Tabulator | 2,155 | 68 | 43 | 47 | 8.0 |

To house these machines and the personnel operating them a room measuring approximately 17 ft by 25 ft would be required, as illustrated on the plan at the end of this report.

# PART VII

## PERSONNEL REQUIRED

If all or most of the problems discussed were given to the machine then the personnel required would be as follows :-

(a) Three personnel to operate the installation. These would of necessity need some technical background, preferably former members of one or other of the sections or departments which would be relieved by the machine. They would not, however, require specialised knowledge or qualifications such as a Mathematics degree.

(b) A supervisor of the section who, of necessity, would have to possess a Mathematics degree. This is essential if fresh problems are to be properly programmed to the machine. Also, if vibration work is to be given to the machine and full advantage is to be taken of it, then the supervisor must also possess experience and knowledge of modern vibration theory. These qualifications are essential if full and proper use is to be made of the machine.

If as experience is gained further work is provided for machine calculation then extra personnel would have to be taken on accordingly, or, a calculating machine of increased capacity would have to be rented. The possibility of doing this is one of the advantages of renting one of the I.B.M. series of machines.

## PART VIII

## TIME, MANPOWER, AND ECONOMICS

I.B.M. do not sell their equipment; their machines are made available on a monthly rental basis. There are a number of advantages to be gained from this from our point of view as it means that we can change our equipment as we require and at no loss to ourselves.

The rental per month of the calculating machine and ancilliary units that we require are contained in the following table :-

| Machine Description | Monthly Rental | | |
| --- | --- | --- | --- |
| | £. | s. | d. |
| Type 116 Numeric Key Punch | 6. | 9. | 0 |
| Type 155 Numeric Verifier | 7. | 3. | 0 |
| Type 080 Model 2 Sorter | 8. | 19. | 0 |
| Type 077 Collator | 28. | 12. | 0 |
| Type 513 Reproducing Punch equipped with 45 columns of comparing and 10 positions of double punch and blank column detection | 23. | 8. | 0 |
| Type 602-A Calculating Punch (full capacity) | 123. | 15. | 0 |
| Type 420 Accounting Machine equipped with 55 type bars 32 adding and subtracting counters, 80/80 speed, and special programming device | 78. | 11. | 0 |
| TOTAL PER MONTH | £276. | 17. | 0 |

In addition we require a counter and sorting tray with brackets - both for use on the sorter - which can be supplied for a total cost of £24. 5. there being no monthly rental required for these pieces of equipment. We would also need 15 extra control panels for the 602-A, 2 for the Collator, 2 for the Reproducer, and 1 for the Tabulator which could be supplied for an initial charge of £344. 8. and again there would be no rental required.

Cards are supplied at 16/3d per 1,000 for plain manilla and 16/8d per 1,000 for plain manilla with coloured stripe, plus delivery charges. We estimate that the consumption of cards will be of the order of £10 per month.

In addition we would require a Friden desk calculating machine, for preparing information for the main calculator, which could come from the present Blade Detail Department; and a number of cabinets for filing cards, control panels etc would be required.

We have estimated that the machines could be programmed and operated by one experienced mathematican and three other people of the standard of the present Blade Detail Section.

We have attempted to make a rough comparison of the savings to be expected on this basis.

(i) BLADE DETAILING

We estimate that the calculator would relieve the blade detail section of work that at present employs six of their personnel full time. We have suggested that three of these personnel become the operators of the machine installation and thus the savings in man-power amount to three personnel. These last three could with advantage be transferred to the Tool Office to perform the drawing of sections on to transparent masters with mechanical aid. The savings on the three personnel would amount to about £100 per month to the Blade Detail Department. In addition there would be a saving in time of issuing blade detail drawings to the shops which would average about a fortnight for a compressor of about 15 stages. The value of this saving is difficult to estimate, but it is clearly considerable.

(ii) STRESS OFFICE

The volume of stress work that the machine could deal with in addition to the blade details is considerably more than that entailed by the blade detail job alone. On the stressing of discs and tubes and the routine vibration calculations we estimate that the equivalent work of four personnel could be done on the calculator. This represents a value of approximately

£200 per month. The existing personnel would therefore be freed for carrying out work that at present there is not sufficient time to investigate in as great a detail as is desirable and also for increasing our output on other work. In addition to the effective saving of £200 per month the calculator would be given work such as determining the rate and stresses of cones that is not done in the Stress Office at the moment due to the prohibitive labour involved. We could also tackle some large scale frequency work in much greater detail than has been possible in the past and have the answers available sufficiently early in the design stage to be of real value.

Over and above all this effective saving there is the important factor of the considerable saving in time that would be achieved. On a lot of the work discussed this would amount to approximately 90% of the present time taken.

(iii) PERFORMANCE - HUCKNALL AND DUFFIELD BANK HOUSE

We have had a very brief discussion with Gtx/EGH on the subject of aircraft performance estimates and we think that saving of money and time of the order of £50 per month and one week in each performance estimate for a given aircraft could be achieved. Aircraft performance estimates are always required rapidly.

Some of the work at Duffield Bank House is of similar character and the possibilities of investigating the optimum combinations of engine and aircraft in greater detail than at present is very attractive.

(iv) COMPRESSOR CHARACTERISTICS

GLW's department would like to calculate more compressor stage characteristics, but this is not a big item and would not be equivalent to the full time work of one junior performance calculator.

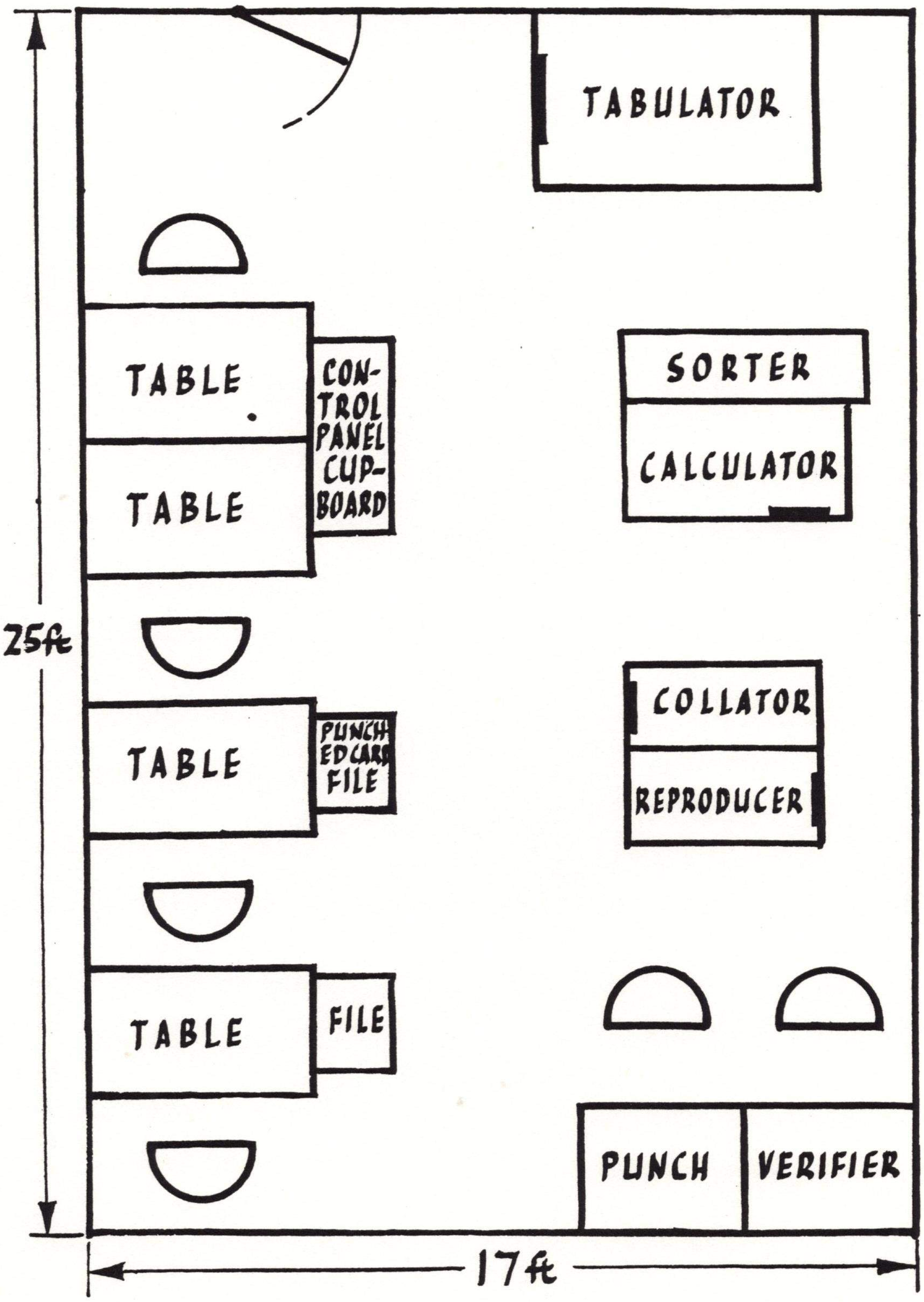
(v) COMBUSTION PROBLEMS

The routine averaging of combustion chamber traverses on the machine would probably not save the time taken to transport the data to and from Sinfin, but the Combustion Department like the Stress Office, have one or two problems that they have not tackled because of the mathematical labour involved.

(vi) INVOLUTE TEETH FOR RING AND PLUG GAUGES

This job arises in the inspection of involute form teeth. In the case of gears we use Maag or Fellows inspection machines and no ordinates have to be calculated but for ring and plug gauges for involute splines the Tool Office do require ordinates. The tabulator could be used for a large part of this job although some time would be required on the other machines, particularly the Collator for looking up involute functions as well as sines and cosines. The job is a sporadic one but we estimate that the time saved would be one week per set.

# GENERAL ARRANGEMENT OF COMPUTOR SECTION




SUGGESTED LAYOUT OF COMPUTOR INSTALLATION SHOWING THE SIZE OF ROOM AND A CONVENIENT SPACING OF THE SEVEN I.B.M. UNITS REQUIRED AND OFFICE EQUIPMENT

SCALE 1/4 in. = 1 ft.