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NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

GENERAL PURPOSES COMMITTEE

Machine Estimate for Nimrod

Paper by the Deputy Chairman of the Project Committee

- 11/2A
1. The Committee requested at their meeting on the 22nd October, 1959 that the cost of the Project should be reviewed and a contingency figure included within which the whole Project would be completed. The revised building estimate was considered and adopted at the meeting on the 11th February 1960 but the review of the machine estimate had not been completed by that date.
 2. This review has now been completed and has taken into account all foreseeable requirements to complete the machine to meet the initial specification and all claims from Contractors which had arisen, or were anticipated up to the 29th February 1960, but excludes increased wage awards under C.V.C.2. It also excludes any import duty which may be payable on plant supplied from overseas.
 3. In reviewing the estimates it remained apparent that there are still a few areas of uncertainty. These are brought out in the appendices, and since detailed engineering designs or specifications are not available in these cases, all that can be done is to include in the estimates a sum which the best consensus of opinion regards as a reasonable provision, and also to include a large contingency allowance.
 4. In compiling these estimates a figure has been included for every item which at present can be foreseen as necessary to complete the machine to meet the original specification. A contingency figure has been shown separately to cover unforeseen difficulties associated with these items. With a project of this magnitude and complexity additional items could still arise which will prove essential for the proper functioning of the machine to the agreed specification. No allowance for these items has been made in estimates and the contingency sum could be inadequate to cover such items.
 5. The following table shows the revised estimate and contingency allowance:-

	Present Treasury Approval	Latest Estimate reported to G.P.C.	Revised Estimate	Contingency	Estimate including Contingency
	£	£	£	£	£
Magnet	2,652,000	2,823,000	3,223,500	325,750	3,549,250
Injector	450,000	450,000	485,000	62,750	547,750
R.F. System	150,000	150,000	164,000	20,000	184,000
Vacuum System	780,000	905,000	1,249,500	243,000	1,492,500
Power Supplies	1,300,000	1,300,000	1,394,000	102,500	1,496,500
Control System	150,000	150,000	150,000	15,000	165,000
TOTAL	5,482,000	5,798,000	6,666,000	769,000	7,435,000

Total commitment to 31st March, 1960 - £4,362,946.

6. The greatest increases are associated with the Magnet, Vacuum System and Injector; increases in the other sections are comparatively small. Reasons for the increases are detailed in the Appendices, but the following additional remarks are relevant.
7. The largest increase in the estimate for the Vacuum System is in the cost of the vacuum chamber. This increase is due to:-
- (i) the difficult engineering design and development work required before it is possible to manufacture large unique components in basically new materials.
 - (ii) the provision of special tools, plant and equipment, and the high cost of prefabrication of the production components.
- An attempt has been made to forecast the final cost of the chamber, but until a prototype octant has been manufactured and tested, there must remain some uncertainty, and for this reason an overall contingency sum of 20% is considered necessary.
8. The Magnet Estimate has increased by 24% since the original estimate. In this section the largest contract, namely that for the supply of the Magnet Sectors is almost complete, and the final price per sector has been negotiated. The pole piece contract is, however, much less firm as the components are in the development stage, and like the Vacuum Vessels involve novel engineering problems. Furthermore, prototypes must be produced and tested in the laboratory on models before the main production can start. For this reason development work will continue at the contractor's works to prove manufacturing techniques, and further changes in design could arise from the model tests. This situation is responsible for the considerable increase in pole piece estimates and the large contingency allowance.
9. To arrive at a reasonable figure for the installation of the machine, a study has been made of the costs disbursed in installing part of the Injector, the model magnets, and associated equipment. The total estimated cost of installation, i.e. £720,000, is approximately 11% of the associated plant, and although exceeding previous estimates by £220,000, is not considered an unreasonable figure for large engineering plant and equipment which has to be installed and aligned to tolerances usually associated with high class light engineering.
10. The original estimates were not based on a detailed engineering design study, and the final engineering form of the project has been evolving gradually since 1957. Where additional equipment has been found necessary, or there has been a large increase in the estimated cost of a component, this has been discussed at the Project Committee and approval of the General Purposes Committee sought to proceed. Appendix VII shows the history of cost estimates for the machine and buildings, together with the reasons for the increase and the relevant paper references.
11. In designing the machine the expenditure involved in improvements on the original specification has been negligible. In order to ensure that the machine is built to the lowest possible price approximately 95% of the value of contracts placed has been as a result of competitive tender.
12. The original estimates on which Treasury approval was given were compiled in March 1957. Since that date there have been increases in the costs of labour and materials, which in some cases have affected the cost of equipment for this Project. This is particularly true where the contract has been placed two or three years after preparation of the initial estimate.
13. Authority is requested for expenditure to be incurred on the Machine up to a limit of £7,435,000 inclusive of a contingency of £769,000. This being an increase of £1,953,000 on the present Treasury approved estimate.

F.A. VICK

Deputy-Chairman, NIMROD Project Committee

NIMROD MACHINE ESTIMATES

MAGNET SECTION

1. The revised estimate of £3,223,500 is an increase of £400,500 above the sum of £2,823,000 approved by the General Purposes Committee. An additional sum of 10% of the Magnet estimate, i.e. £325,750 is recommended to cover contingencies on those items included in the estimate.

2. Octant End Structures

The estimate for the octant end structures is increased by £10,000 to provide for magnetic shielding of the straight sections.

3. Baffles for Air Flow

Experimental work has confirmed that baffles will be necessary between the sectors to direct cooling air to those parts of the sectors where it is most needed to maintain the geometry of the magnet gap. No provision was made in the approved estimate for these baffles, and it is now estimated that £6,000 will be required (i.e. approximately £18 per magnet sector). Provision of £1,800 was made in the Building Estimates for nozzles which have now been deleted. This saving has been taken into account in the recent revised Building Estimates.

4. Magnet Main Coils

4.1 It was originally intended to connect the magnet cables to the coil ends. It has now been found necessary to accommodate protective spark gaps close to the magnet coil ends, which makes bus-bars between the cables and the coil ends necessary. Stands will be provided to support both the bus-bars and the spark gaps. The additional cost of bus-bars and stands is estimated to be £3,500.

4.2 To ensure that the front face of the coil layers is flat to within an acceptable tolerance, it has been found necessary to provide additional leatheroid packing, at an estimated cost of £3,400, at the back of each coil layer in the magnet sector throat, since the tolerance on insulated coils will be too wide.

4.3 The use of cone type water connections has resulted in more difficult machining on the longitudinal and end conductors. The additional cost is estimated to be £3,500.

4.4 In order to be assured that the brazed joint between the cadmium copper block and the longitudinal conductors is sound the Project Group have asked the Contractor to carry out certain fatigue tests at an estimated cost of £3,600.

4.5 The contract price for the coils includes the cost of a lifting beam for the 50' long conductors. The contractor has been unable to accommodate the checking fixture for these conductors, which was requested by the Group, at their main works and it has been installed at a subsidiary works. As a result of this, it is necessary to provide a second lifting beam at a cost of approximately £1,500.

4.6 A further lifting beam and the trolley for use with it is required to enable the contractor to transport the long conductors from their stockpile into the workshop. The estimated cost of this is £1,100.

4.7 To ensure that the conductors are within the required tolerance after delivery to site, it is now proposed to provide one checking jig for checking the curvature of the long conductors, one jig for checking the end conductors and a suitable straightening fixture. The estimated cost of this equipment is £6,000.

5. Pole Pieces

5.1 It will be recalled that the contract for manufacture of the main pole pieces was placed with English Electric Company in the sum of £227,000 before design details had been agreed. It is not possible to determine the final cost of manufacture until prototype pole pieces have been manufactured and tested. It is already clear, however, that a considerable increase in the provision for this item in the estimate will be necessary, and the best estimate which can be made on the information at present available is £350,000 for main pole pieces. This represents an increase of £120,000 over the provision of £230,000 in the Approved Estimate.

5.2 To meet the pole piece installation programme, it is necessary to provide handling equipment to enable four teams to operate simultaneously. The number of pole piece handling trolleys provided for in the estimate has therefore been increased from two to four and the number of pole piece withdrawal mechanisms from three to four. These trolleys and withdrawal mechanisms are more complex than was originally envisaged, due to the fact that the pole pieces are now within the outer vacuum vessel. The estimate for pole piece handling equipment has therefore been increased by £12,000.

6. Pole Face Windings

6.1 A sum of £80,000 is provided in the present approved estimate for pole face windings and associated handling equipment. A preliminary survey of market prices has indicated that this is inadequate. No firm cost figures are available but the best estimate is £160,000.

6.2 As a result of experience gained with the chilling units being used on site for other purposes, the estimate for pole face winding chilling units has been increased by £6,000 to provide for agitators to enable lower temperatures to be achieved, and for the lagging of all flow and return pipes and valves.

7. Installation

Experience with Model VI has shown that the provision for installation of the main coils is inadequate. It is now known that the provision for installing pole pieces and pole face windings will be insufficient, because of the difficulties arising from the fact that these items are now inside the outer vacuum vessel. In addition, it is now clear that this installation work will have to be carried out by specialist contractors at skilled labour rates. The estimate for installation for all items in the Magnet Section is increased by £164,000.

8. A summary of the above increases in the Estimates on this section is as follows:-

<u>Item</u>	<u>Increased by:</u>			
				£
Octant End Structures	...	...	...	10,000
Baffles for Air Flow	...	...	...	6,000
Magnet Coils	...	...	...	22,500
Pole Pieces	...	...	...	112,000
Pole Face Windings	...	...	...	86,000
Installation	...	...	...	164,000
Total Increase				<u>£400,500</u>

NIMROD MACHINES ESTIMATESINJECTOR SECTION

1. The revised estimate of £485,000 is an increase of £35,000 over the sum of £450,000 approved by the General Purposes Committee. An additional sum of 13% of the Injector estimate, i.e. £62,750, is recommended to cover contingencies on those items included in the estimate.

2. D.C. Gun

As a result of small increases in a number of items, the final cost of the D.C. Gun will be £1,000 higher than was originally anticipated.

3. R.F. Liner of the Linear Accelerator

It is now known that the R.F. Liner of the Linear Accelerator is likely to cost about £4,000 more than the provision of the estimate. This is due to two factors. First, strike action at the works of the suppliers of stainless steel supporting rings caused serious delays at the contractor's works, and as the Authority undertook to supply these rings, the contractor for the Liner has submitted claims for overtime and other related expenses necessarily incurred to enable them to deliver by an acceptable date. Secondly, the method of inspection specified by the Group after the contract was placed, to ensure accuracy of this important component, has cost more than the contractor had allowed in his price.

4. Drift Tube Assemblies

4.1 The contract for this item was placed with B.O. Morris Limited, in the sum of approximately £58,000. The provision of £60,000 in the estimate allows for normal design modifications after the placing of the contract, and the estimate has not been increased.

4.2 The most critical stage of this difficult work viz. final welding of shells, has only just been reached and the production of 48 satisfactory assemblies may well entail much more labour than is allowed for in the contract price. A contingency of 25% of the estimate i.e. £15,000 is required.

5. Roughing Pump System

Design information now available on the Main Roughing Pump System indicates that greater runs of line, together with some valves, vacuum gauges, etc., are required. The increase in the estimate is £2,800.

6. High Energy Drift Space

Maturing consideration of the requirements of this section has shown the present approved estimate to be inadequate. There is still insufficient information to enable reliable estimating to be done, but the sum of £30,000 is the best estimate which can be made at present. This represents an increase of £4,000.

7. Inflector

Owing to space restriction at the octant ends, it has become necessary to adopt a more complex inflector system. For example, four Highly Stabilized Deflector Magnets are required, compared with one previously envisaged, and two 12" Diffusion Pumps must now be included. A large increase in the cost must therefore be expected, but there is insufficient information to allow reliable estimating to be done. A figure of £40,000 is the best estimation which can be made at this stage and represents an increase of £23,000 over the approved estimate.

Appendix II (Contd.)

8. A summary of the above increases in the Estimates on this section is as follows:-

<u>Item</u>	<u>Increased by</u>
	£
D.C. Gun	1,000
Linac R.F. Liner	4,000
Roughing Pump System ..	3,000
H. E. Drift Space	4,000
Inflector	23,000
Total Increase	<u>35,000</u>

NIMROD MACHINE ESTIMATESR.F. SYSTEM SECTION

1. The revised estimate of £164,000 is an increase of £14,000 over the sum of £150,000 approved by the General Purposes Committee. An additional sum of 12% of the R.F. System estimate, i.e. £20,000 is recommended to cover contingencies on those items included in the estimate.
2. Drive Chain

It was previously intended to make up the Low Power and High Power amplifiers and cubicles for the drive chain in the laboratory, but it is now thought that this equipment will require an engineering design prior to manufacture by industry. Competitive tenders will be sought. The estimate for this item has been increased by £8,000.
3. Primary Frequency Generator

The estimate for this item has been increased by £4,000 as a result of Nuclear Physicists requirements not previously envisaged and not provided for in the approved estimate, which has remained unchanged since the beginning of the project. Additional channels are now required in the Timing Unit in the Primary Frequency Generator at a cost of £2,200. A display rack carrying special digital monitors to cover the requirements for the Nuclear Physicists is required, at an estimated cost of £1,800.
4. Beam Control Unit

A travelling Wave Monitor and remote and local controls, replacing manually pre-set type are new requirements to meet the needs of the Nuclear Physicists. The additional cost amounts to approximately £2,000.
5. A summary of the above increases in the Estimates on this section is as follows:-

<u>Item</u>	<u>Increased by:</u>
Drive Chain	£8,000
Primary Frequency Generator ..	£4,000
Beam Control Unit	£2,000
Total Increase	<u>£14,000</u>

NIMROD MACHINE ESTIMATESVacuum System Section.

1. The revised estimate of £1,249,500 is an increase of £344,500 above the sum of £905,000 approved by the General Purposes Committee. An additional sum of 19.5% of the Vacuum System estimate; i.e. £243,000 is recommended to cover contingencies on those items included in the estimate.

2. Main Vacuum Vessels

The estimate for the main vacuum vessels is increased from £465,000 to £683,000. The contract for development of the first octant and manufacture of subsequent octants was placed with Marston Excelsior. It will be recalled that it was not possible to place this Contract at a fixed price and the revised estimate in the light of experience to date is made up as follows:-

Development of a prototype octant	£160,000
Manufacture of tools	£200,000
Production of the prototype octant	£ 37,000
Production of further 8 octants	£260,000
	<u>£657,000</u>

The reasons for the increase in the estimated costs of development and tools are set out in detail in Paper N.I(GP)(60)20.

The estimate for the production octants has been revised to £260,000 which is an increase of £50,000 on the first estimate. This is an area of uncertainty until the prototype octant has been tested and Marstons have quoted a fixed price. The sum of £260,000 is however the best assessment possible at this stage.

There are in addition further items, e.g. windows and ports in the header vessel, not covered by this Contract, the estimated cost of which is £26,000.

3. Sealing Diaphragms

This was a new requirement consequent upon the change to a double walled vacuum vessel. The estimate has been increased by £5,500 on receipt of detailed design information.

4. Differential Pressure Valves

This is another item which resulted from the change to a double-walled vessel. The estimate has been increased by £2,000 from the original token sum in the light of design information now available.

5. Straight Sections

Although no detailed design information is available on the Straight Sections, it is now clear from the cost of comparable equipment (e.g. the beam control vessel) that the provision in the estimate is inadequate. Reliable estimating is not yet possible, but the best assessment which can be made at this stage is £36,000 based on the assumption that the material used will be principally stainless steel. This is an increase of £21,000.

6. Main Pumping Units

Experience during testing of the first pumps delivered shows it is necessary to provide lagging around the pump cooling services to prevent condensation. The costs of the pump suspension units as now designed is greater than the contractor had allowed for in his price. For these reasons, the estimate for main pumping units has been increased by £5,000.

7. Roughing Lines, Valves and Oil Traps

A greater number of valves, roughing lines and oil traps are required consequent upon the increased number of roughing pumps, and the estimate is increased by £7,000.

8. Bellows Units

Enquiries to industry for this specialised equipment indicate that the provision in the Approved Estimate will be inadequate. As full design information is not yet available, reliable estimating is not possible, but the best assessment of cost which can be made is £40,000, which is an increase of £20,000.

9. Pump Headers

Experience at Marston's with Main Vacuum Vessels now makes it evident that the rate per pound allowed in the previous estimate for complex shapes made in epoxy resin glass fibre laminates was too low. The estimate has, therefore, been increased by £13,000.

10. Installation

It is now clear that the techniques involved in installing the double-walled type of vacuum vessel demand the use of specialist contractors working at skilled labour rates. The effect of this on the estimate is an increase of £53,000.

11. A summary of the increases in the Estimates for this section is as follows:-

<u>Item</u>	<u>Increased by</u>		
			<u>£</u>
Main Vacuum Chamber..	..	..	218,000
Sealing Diaphragms ..	..	..	5,500
Differential Pressure Valves		..	2,000
Straight Sections ..	..	..	21,000
Main Pumps	..	..	5,000
Roughing lines, valves and traps	..	..	7,000
Bellows units	..	..	20,000
Pump headers	..	..	13,000
Installation	..	..	53,000
Total Increase			<u><u>344,500</u></u>

NIMROD MACHINE ESTIMATESPOWER SUPPLIES SECTION

1. The revised estimate of £1,394,000 is an increase of £74,000 over the sum of £1,320,000 approved by the General Purposes Committee. An additional sum of 7½% of the Power Supplies estimate, i.e. £102,500 is recommended to cover contingencies on those items included in the estimate.
2. 2.1 The design of the foundation block for the Motor Alternator Set involves unique problems and after consulting several specialists, it has been decided to adopt longitudinal post-tensioning of the concrete. A revised quotation is due from the Contractor and the actual cost will not be known until this is received. Reliable estimating on this item is not possible, but the best assessment of probable cost at this stage is £80,000 which represents an increase of £20,000 over the approved estimate.

2.2 Visual and ultra-sonic inspection of the Motor Shaft via the Bore Hole is being adopted as a result of the Berkeley Shaft failures. As a result of this it is necessary to polish the shaft internally. It has also become necessary to re-design the main Motor Bed Plates to give greater strength and rigidity. These two items have resulted in an increase of the estimate of £2,000.
3. Power Supply for Pole Face Windings

A token sum of £5,000 was included in the original estimates for this item. There is, as yet, no basis for reliable estimating beyond the knowledge of the total power requirements and from this it is clear that the sum in the approved estimate is inadequate. The best assessment of cost possible, at this stage, is £40,000.
4. Ripple Filtering Equipment

The Project Committee at their meeting on the 8th April, 1960, approved in principle a scheme for reducing the effect of Ripple Voltages. This involves the use of two large transformers of approximately 50 tons each, the actual cost of which is not yet known. The best assessment of the cost of the scheme including installation, which can be made at this stage is £97,000 which is an increase of £17,000 over the notional sum included in the Approved Estimate.
5. A summary of the above increases in the Estimates on this section is as follows:-

<u>Item</u>	<u>Increased by:</u>
Foundation Block	£20,000
Rotating Machinery	£ 2,000
Pole Face Winding Power Supply .	£35,000
Ripple Filtering Equipment . .	£17,000
 Total increase	 <u>£74,000</u>

TABLE SHOWING COMPARISON OF APPROVED ESTIMATES

	Original Treasury Approval	QUARTERLY STATEMENTS						
		No.1 12. 10. 57.	No.2 4. 1. 58.	No.3 31. 3. 58.	No.4 21. 6. 58.	No.5 19. 9. 58.	No.6 21. 1. 59.	No.7 31. 3. 59.
<u>PLANT</u>								
Magnet Injector	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
R.F.	0.30	0.30	0.30	0.30	0.30	0.45	0.45	0.45
Vacuum	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Power Supply	0.40	0.40	0.40	0.40	0.46	0.50	0.78	0.78
Controls	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Cooling	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	0.10	0.10	0.10	0.10	0.10	-	-	-
PLANT TOTAL	5.00	5.00	5.00	5.00	5.06 ^a	5.15 ^e	5.43 ^g	5.43
<u>BUILDINGS</u>								
Architects	1.40	1.34	1.34	1.48	1.48	1.46	1.51	1.53
M. & E.	0.40	0.54	0.54	0.55	0.55	0.56	0.56	0.57
Fees	0.10	0.15	0.15	0.15	0.23	0.23	0.23	0.23
Furniture	-	-	-	0.03	0.03	0.03	0.03	0.03
BUILDING TOTAL	1.90	2.03 ^a	2.03	2.21 ^b	2.29 ^d	2.28 ^f	2.33 ^h	2.36 ⁱ
GRAND TOTAL	6.90	7.03	7.03	7.21	7.35	7.43	7.76	7.79

a) Cost of Arcon Building and revision of Estimates (Paper NI GP 57.3 refers)

b) Revised Estimates including cost of furniture

c) Revised estimates for Vacuum Pumps (Paper NI GP 58.6 refers)

d) Industrial Groups fees included

e) Revised Estimates on Injector. £100,000 re-allocated from Cooling system as follows; £80,000 to Injector and £40,000 to Vacuum system.

f) Slight decrease due to re-estimating

g) Redesign of Vacuum Chamber. The design information was not sufficiently complete to allow a firm estimate at this stage.

h) Additional works approved by Project Committee listed in Appendix 1 of Quarterly Statement No. 6

i) Re-estimating following approval of design details and various additional works listed in Appendix 1 of Quarterly Statement No. 7

TABLE SHOWING COMPARISON OF APPROVED ESTIMATES

PLANT	Original Treasury Approval	QUARTERLY STATEMENTS			Present GPC Approval	Latest Revised Estimate
		No. 8 30. 6. 59.	No. 9 30. 9. 59.	No. 10 31. 12. 59.		
Magnet Injector R.F.	2.60	2.823	2.823	2.823	2.823	3.224
Vacuum	0.30	0.450	0.450	0.450	0.450	0.485
Power Supply	0.15	0.150	0.150	0.150	0.150	0.164
Controls	0.40	0.905	0.905	0.905	0.905	1.249
Cooling	1.30	1.300	1.300	1.320 ^l	1.320	1.394
Contingency on above Plant items	0.15	0.150	0.150	0.150	0.150	0.150
	0.10	-	-	-	-	-
	-	-	-	-	-	0.769
PLANT TOTAL	5.00	5.778 ^j	5.778	5.798	5.798	7.435
BUILDINGS						
Architects	1.40	1.591	1.591	1.888	1.888	1.888
M. & E.	0.40	0.667	0.667	0.701	0.701	0.701
Fees	0.10	0.232	0.232	0.303	0.303	0.303
Furniture	-	0.030	0.030	0.030	0.030	0.030
Contingency on above Building items	-	-	-	0.179	0.179	0.179
BUILDING TOTAL	1.90	2.52 ^k	2.52	3.101 ^m	3.101	3.101
GRAND TOTAL	6.90	8.298	8.298	8.899	8.899	10.536

j) Increase in cost of magnet and vacuum system (see notes to Appendix I of Quarterly Statement No. 8.

l) Increase in cost of Rotating Machinery foundations (Paper NI (GP) (59) 46 refers)

k) Increase in building estimate due to rise in estimate for Engineering Services (Quarterly Statement No. 8 refers) and increase in estimate for main surface water scheme (Paper NI GP 59.19) refers

m) Building Estimate increased and contingency added, explained in Paper NI (GP) (60) 3.