SOLAR POWER FOR REMOTE AREAS
FLUID HEATING 200°C AND ABOVE

PROGRESS REPORT

JULY 1979

P O CARDEN

ENERGY CONVERSION GROUP
DEPARTMENT OF ENGINEERING PHYSICS
THE AUSTRALIAN NATIONAL UNIVERSITY

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FLUID HEATING 200^{o}C AND ABOVE

Progress Report

July 1979

Presented by

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ACKNOWLEDGEMENT

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CONTENTS

1. SUMMARY

Project Title: Solar power for remote areas; fluid heating to $200^{o}C$+.

Organisation: The Australian National University, Department of Engineering Physics (Energy Conversion Group).

Project Leader: P O Carden, ME, PhD

Objective: To develop designs and methods of manufacture which will result in cost-effective paraboloidal mirror collectors capable of providing fluid heating at $200^{o}C$ or more. To involve industry in this development. To test the collectors in an industrial fluid heating application. To adapt them for the production of superheated steam to power a 25 kw steam engine suitable for generating power in a remote area. To further adapt the collectors to the dissociation of fluids suitable for thermochemical energy transfer (this method is appropriate for power generation on a larger scale, eg. 1 MW and above). To observe the operation of pilot plants using these collectors and so determine the cost factors attributable to operation, maintenance and depreciation. To carry out research and development aimed at reducing all cost factors.

Work Programme: Complete the construction of a vacuum operated sheet metal press capable of forming paraboloids 3.6 m diameter (10 m^2 area). Continue development of a method of manufacturing a reflective liner based on the concept of moulding an acrylic sheet which is subsequently back-silvered (or aluminised). Continue development of a torque amplifier which may enable a cost reduction by replacing the most costly component of present sun-tracking collectors viz the actuators based on gear trains. Continue development where necessary of all other components of a solar fluid heating system with the object of constructing such a system as soon as possible. Prepare plans for the installation of a system at the

Bathurst factory of Uncle Ben's of Australia. Plan the adaption of the collectors to the generation of superheated steam for a steam engine (eg. that developed by Pritchard Steam Power Pty Ltd, Melbourne). In all the above, consult with industry wherever possible in order to obtain authentic cost estimates and to ensure a smooth transition from development to industrial manufacture.

Project Status: Construction of the vacuum press has been proceeding for 6 months and a further 6 months will be required for its completion. Most of the components have been made except for the paraboloidal die. Cast aluminium segments (which are to be welded together) have been ordered for this and their delivery is now three months overdue. A boring mill attachment has been designed for milling the parabolic form but construction has not yet commenced. The design of the press has been based on a 60 cm scale model which is working satisfactorily. The paraboloids produced by the model have been subjected to wind load tests and accuracy measurements.

The development of the reflective liners is also proceeding on model scale. Paraboloidal acrylic liners have been produced with good surface finish and accuracy. Moderate success has been achieved so far with jointed acrylic sheets. Our industrial consultants have begun silvering tests.

The development of the collector control system is about 20% complete.

The design of the collector mounts is sufficiently complete for cost estimates and these have been obtained.

A prototype torque amplifier has been built and is being tested. Results are encouraging.

Given adequate funds we expect to complete the first pair of tracking collectors in fifteen months time. However, we have committed all of the 1978-79 allocation and lack of continuing finance through 1979-80 is seriously affecting progress.

2. INTRODUCTION

The work of the Energy Conversion Group this year has been aimed towards meeting the specific objectives set out by the NERDDC standing committee viz:

a. Specify and prepare, in conjunction with an engineering company, systems drawings and a cost estimate (+/- 25%) of a demonstration project including all elements.

b. Carry out development work to prove feasibility and cost of producing large parabolic dishes using a vacuum press.

c. Carry out development work on critical system elements (eg. reflective surface application and torque amplifier for steering) to prove feasibility and cost of manufacture.

In order to meet these objectives, extra staff has been appointed and extra laboratory space has been acquired through the assistance of the Research School of Physical Sciences.

2.1 New Staff

Two persons were engaged in late March on one year appointments

- Engineer Grade I
- Laboratory Technician/draftsman

2.2 New Laboratory

The Energy Conversion Group has moved to a larger neighbouring laboratory which has been refurbished. The move was initiated by the Director of the Research School of Physical Sciences and the cost of refurbishing has been borne by the School.

3. DEVELOPMENT OF CRITICAL ELEMENTS

3.1 Vacuum Press

Manufacture of the 3.6 m press is now well under way in the workshop of the Research School of Physical Sciences. Nine aluminium segmental castings for the paraboloidal mould have been ordered and were to have arrived towards the end of May. However, there has been considerable slippage on these components due to the castings not maintaining the prescribed curvature during cooling. They are not now expected to be delivered until August. When they are delivered they will be welded together and machined on the large boring mill using a machining rig designed to automatically generate the required paraboloidal form.

3.2 Collector Shells

The 60 cm scale model press has enabled us to demonstrate that the concept of press-forming sheet metal paraboloids is practical. It has also provided us with a source of model paraboloids with which to experiment in order to resolve two remaining outstanding questions: determination of the buckling strength in strong winds, determination of the accuracy of press forming.

3.2.1 Wind Tests

In order to determine the buckling wind velocity a model paraboloid was mounted on a frame attached to a vehicle as shown in Figure 1 and subjected to winds of velocities up to approximately 140 km/hr. The vehicle was driven in still air along the main runway of the Canberra airport.

Prior to the tests the rim of the model paraboloid was strengthened by a ring in a manner similar to that intended for the full sized paraboloid. This composite structure was then attached at four equispaced points to a square frame representing the full sized shell sub-frame. The frame was then mounted 2 m clear of the side of the vehicle to avoid disturbed air and oriented so that the axis of symmetry of the paraboloid was horizontal. In all the tests the wind blew against the convex surface of the paraboloid but the angle between its axis of symmetry and the forward direction of the vehicle (the wind angle) was altered for successive tests. The chosen values of wind angle were 0^o, 37^o, 52^o and 67^o.

In all the tests it was observed that the paraboloid did not buckle for vehicle speeds up to the highest achieved: 140 km/h.

However, some local deformation, which proved to be largely elastic, occurred at one mounting point because the paraboloid had been slightly deformed during fitting. The use of flexible mounts will avoid this problem in the future.

Since the test wind velocity exceeds by a factor of two the design gust speed for the collectors in the unclammed position, it has therefore been demonstrated that the collectors have adequate resistance

FIGURE 1: PHOTO OF TRUCK WITH DISH MOUNTED ON SIDE

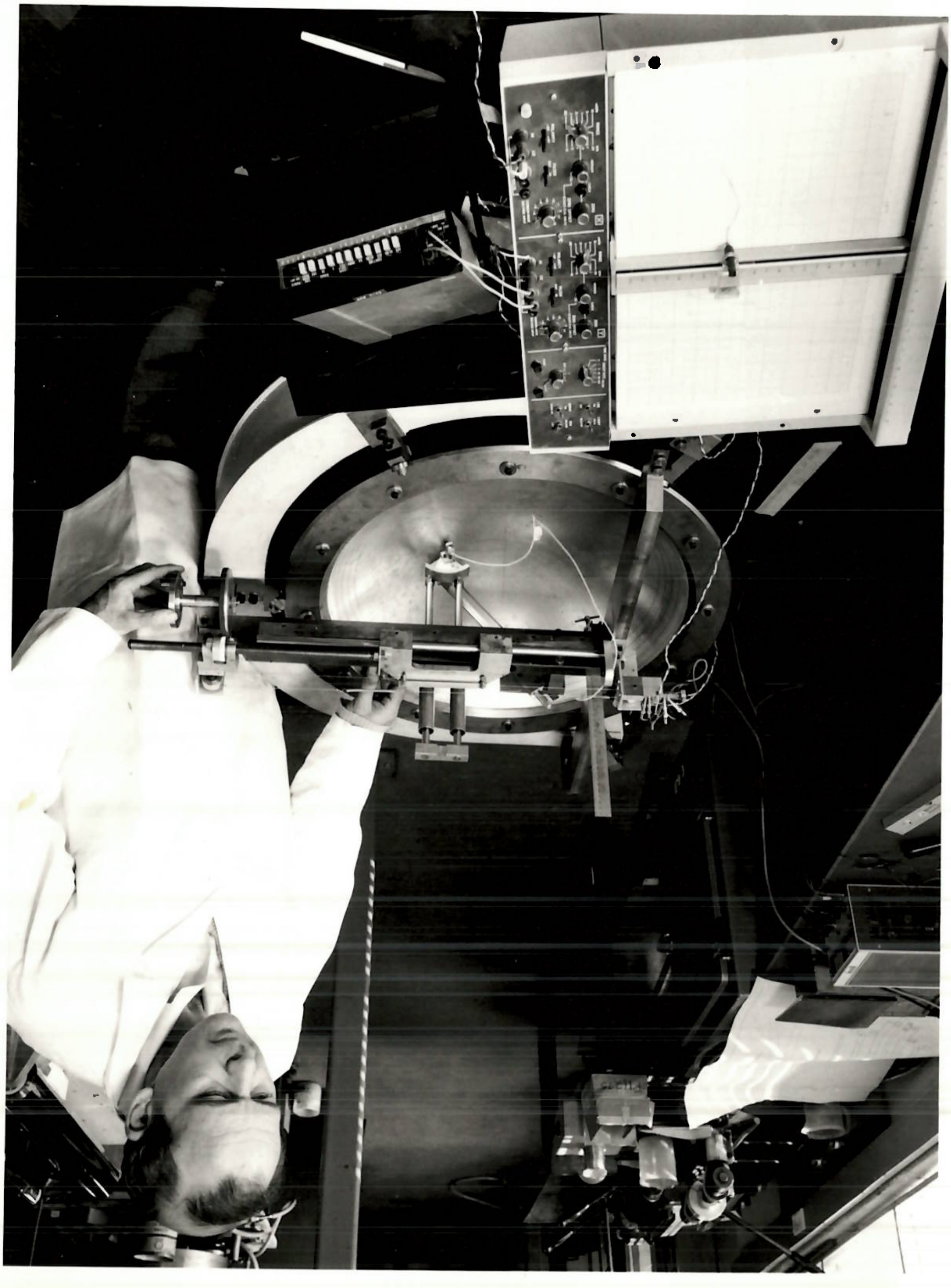
FIGURE 1: Model sheet metal paraboloids were tested for resistance to buckling in winds up to 140 km/hr at the Canberra Airport.

to buckling in the wind conditions prevailing during normal operation. Moreover, because differential pressures for a given wind velocity reduce markedly as the wind angle is changed from 0 to 90^{o}, and since the latter angle corresponds to the clammed configuration, it is quite probable that the collectors will have adequate resistance to buckling in the clammed position for peak wind gusts experienced in most of Australia. However, this needs to be verified by a series of tests in a wind tunnel.

3.2.2 Accuracy

A special jig has been built to enable the accurate measurement of dishes formed on the 60 cm model press. The purpose of these measurements is to establish how closely the dishes approach an ideal paraboloidal form and thus to establish whether it will be necessary to incorporate correcting perturbations into the 3.6 m mould.

Preliminary tests confirm that the operation of the jig is satisfactory. The procedure has been established for preparing slope error polar diagrams of model paraboloids and several preliminary measurements have been made. Although it is too early to draw definite conclusions it appears that we can already produce paraboloids having over half the aperture area within the tolerance of ± 5 miliradians. However the accuracy of the model epoxy die (which was made by spinning liquid resin until it set) is now in doubt because of the prolonged effects of water that has infiltrated the plaster of paris substrate. A second die is to be constructed as soon as possible.



ACCURACY JIG

The accuracy of a model sheet metal paraboloid is measured on this special rig which generates an ideal base parabola. Deviations from the base parabola are measured electronically and recorded on the XY plotter.

The same parabola generating principle is embodied in the design of the boring mill attachment which will be used to machine the vacuum press paraboloidal die.

3.3 Reflective Surface

A decision has been reached to pursue the method whereby thin (approx 1 mm) acrylic sheet is blow-moulded to the correct form, back-silvered, and sealed to the concave surface of the pressed metal dishes. This candidate has been chosen as being the most appropriate for the initial small quantity of collectors to be produced. Development work has proceeded along the following lines:

- collaboration with an appropriate industrial organisation with regard to the silvering process
- laboratory tests of methods of blow moulding
- laboratory tests of appropriate methods of joining flat acrylic sheets prior to blow moulding.

The firm of Oliver Davey, Melbourne, is collaborating with us and has already carried out several silvering tests. This firm operates a large silvering plant and several of its technical staff are widely experienced. Discussions so far have indicated that, although there are aspects to watch, the industry has experience of successfully silvering acrylic. It has yet to be decided whether it would be appropriate at this stage to bring silver nitrate spraying equipment to Canberra. If the silvering is carried out in Melbourne it will be necessary to segment the moulded acrylic sheets or to mould individual segments in order to facilitate transport to and from Melbourne. The advantages of silvering in Melbourne will have to be weighed against the disadvantages of the additional costs of transport, segmenting and sealing to the metal dish.

3.3.1 Acrylic Moulding

A test facility has been set-up in the laboratory for blow-moulding 60 cm diameter sheets. The facility comprises a shallow 60 cm diameter drum open at the top. Across this opening is placed a flat sheet of acrylic. A seal between acrylic sheet and drum is effected by clamping the rim of the sheet between the drum and a super-imposed ring. A second drum is placed mouth downwards over the sheet. The cylindrical walls of both drums are lined with heating coils and all walls are thermally insulated. There is provision for evacuating the lower drum. Thermocouples are disposed within the apparatus to enable measurements of air temperature.

In operation the heaters are used to bring the interior of the apparatus to an even temperature in the vicinity of 150^{o}C. A slight vacuum is then applied to the lower drum which causes the sheet to dish.

The tests performed so far have not uncovered any major difficulties. They have included test sheets comprising several pieces cemented together in a butt joint. In some of these tests a paraboloidal mould has been included. The resulting acrylic shapes now obtained have good accuracy and surface finish.

It has been established that the optimum operating conditions require preheating the acrylic and mould to 140^{o}C prior to forming and then cooling both to 60^{o}C prior to removal of the shape from the mould. The measured linear contraction of 0.6% is not expected to give a significant optical observation.

MOULDED ACRYLIC REFLECTIVE LINER

The model acrylic liner displayed here was formed in the apparatus visible in the background (covered by an inverted transparent liner) and was silvered in Melbourne by Oliver Davy Pty Ltd. Others have been aluminised at the Department of Astronomy, Mt Stromlo.

The tests performed on acrylic sheet made up of sections cemented together indicate that it is possible to make joints of sufficient hot strength to withstand the moulding process. However, a reliable jointing procedure has not yet been established and the joints so far achieved are considerably weaker than the parent material.

3.3.2 Reflective Layer Application

Reflective layers have been applied to the convex sides of several samples of moulded acrylic sheet. All these samples have been spherical with a depth-to-diameter ratio equal to the paraboloid's. The reflective layers have been vapour deposited aluminium (by courtesy of the Department of Astronomy at Mt Stromlo) and silver deposited by reduction of silver nitrate (by courtesy of Oliver Davey).

The aluminised samples appear to have very good reflectance. The silvered samples are first attempts by Oliver Davey and although they are acceptable there is clearly room for improvement. An obvious difficulty to be overcome is removal of a grease-like residue from the surface to be silvered. This contaminant probably originates from the protective film applied by the manufacturer of the acrylic sheet. Oliver Davey are in the process of gathering relevant information from sources throughout the world and should consequently be able to rectify the problem.

Several attempts have been made in our laboratory to mould a pre-aluminised flat sheet. It has been observed that specularity is almost completely lost due both to heating and to the strain during moulding. Similar trials are planned for pre-silvered flat sheet.

3.3.3 Manufacturing Options

Three candidate methods for forming the acrylic shapes have been considered:

a. flat sheets of acrylic are butt joined and trimmed to form circles about 4 m diameter. The vacuum press is adapted to blow moulding these circles by fitting a heating and cooling system;

b. as for a. except that the die is removed from the vacuum press and replaced by a pressed metal paraboloid;

c. flat sheets of acrylic are shaped into triangular segments. A special die is made from a spare aluminium cast segment (eight of which are welded together to form the die of the vacuum press). This segmental die is fitted with heaters, coolers and clamps and with it eight acrylic segments are formed for each collector.

Option a. is not favoured because of the large heat capacity of the cast aluminium die (16 kwhr from 60^{o}C to 150^{o}C) and fear that differential expansion between the die and the steel frame may cause damage.

Option b. has the advantage of low thermal capacity (1 kwhr) and, of the remaining options, requires the least expense to implement. However, it depends on the discovery of a successful jointing technique.

CONCEPT OF A PROCESS FOR MANUFACTURING ACRYLIC REFLECTIVE LINERS

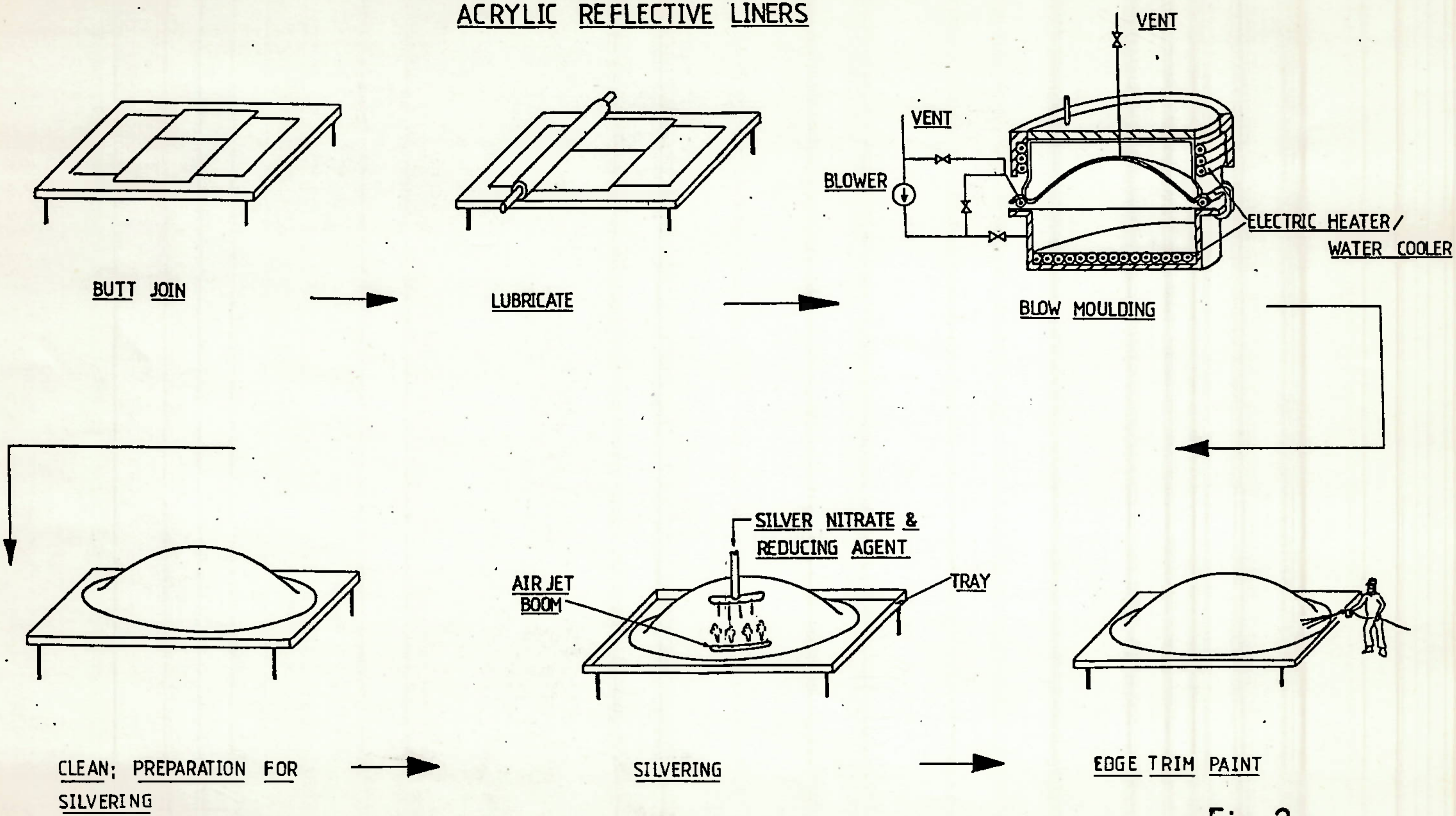


Fig. 2

CONCEPT OF A PROCESS FOR MANUFACTURING ACRYLIC REFLECTIVE LINERS

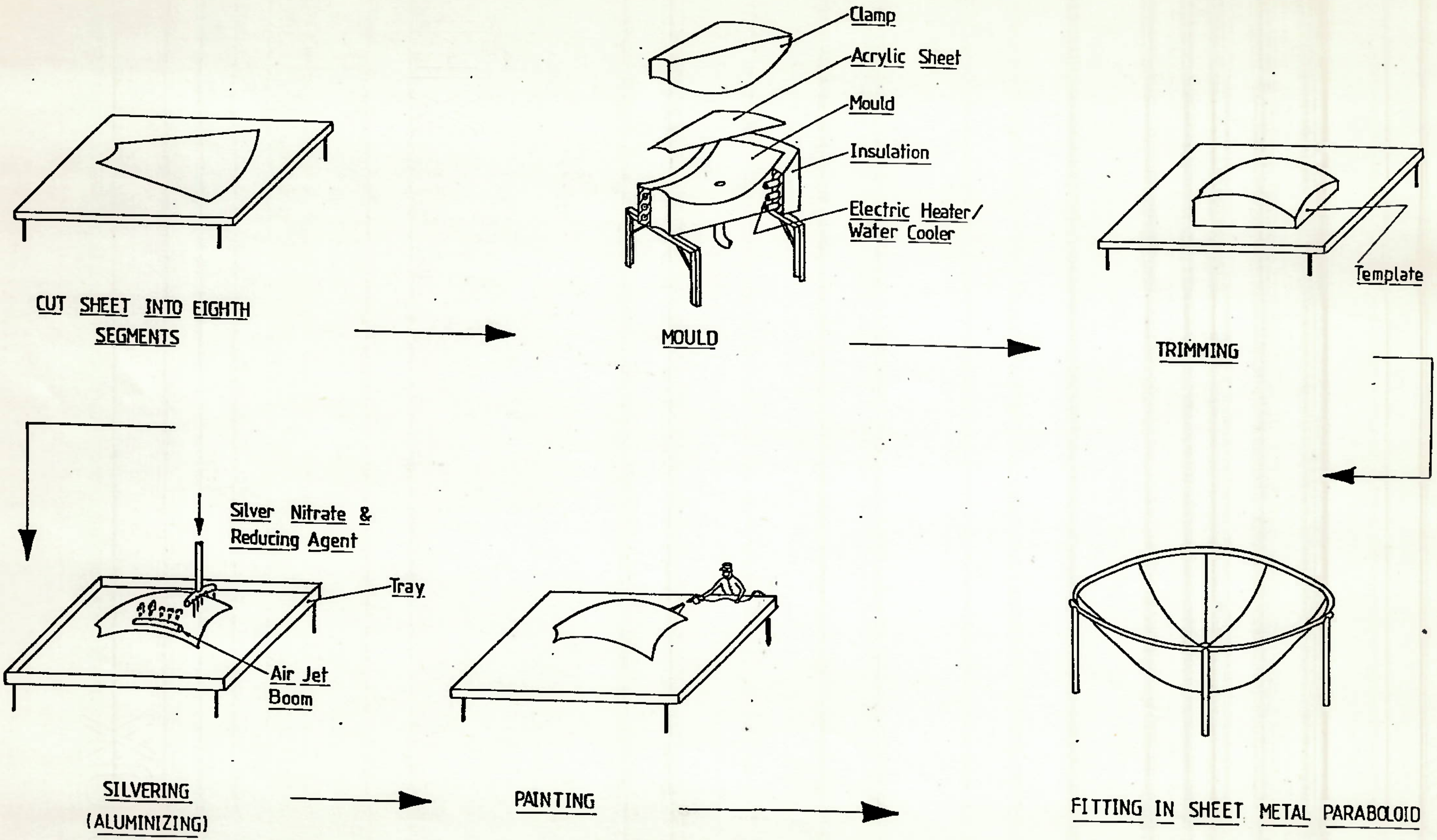


Fig. 3

Option c. is the most expensive to implement not only because of the need to machine a special die but because eight separate shapes must be made and fitted for each collector. However, this option does not depend on the discovery of a jointing technique and allows an extra candidate reflective surface because the segments would be small enough to fit into available aluminium vapour deposition chambers.

Options b. and c. are diagrammed in Figures 2 and 3 respectively.

Of the two reflective surface processes, aluminising is a fairly straight forward process and could be performed either at Mt Stromlo or at Siding Springs. Silvering should also be straight forward. It would involve spraying the solutions of silver nitrate and reducing agent onto the acrylic shape and collecting the run-off in a tray. In order to avoid the wasteful deposition of silver in the run-off tray it is necessary to allow about 20 seconds contact between the solutions and the acrylic surface. For options a. and b. this may present a problem on the steep sides near the rim of the liner but there are several ways of overcoming the problem should it arise, eg. tilt the acrylic liner; employ air jet booms to impede the velocity of the solution as it flows over the acrylic surface.

3.4 Actuator

3.4.1 Torque Amplifier

A prototype of this novel device has been designed and constructed and is now undergoing tests.

We have been motivated to investigate this device because of the high cost of conventional gearboxes: equivalent to 150\$/m^2 each for a collector system whose target cost is 100\$/m^2 of aperture area.

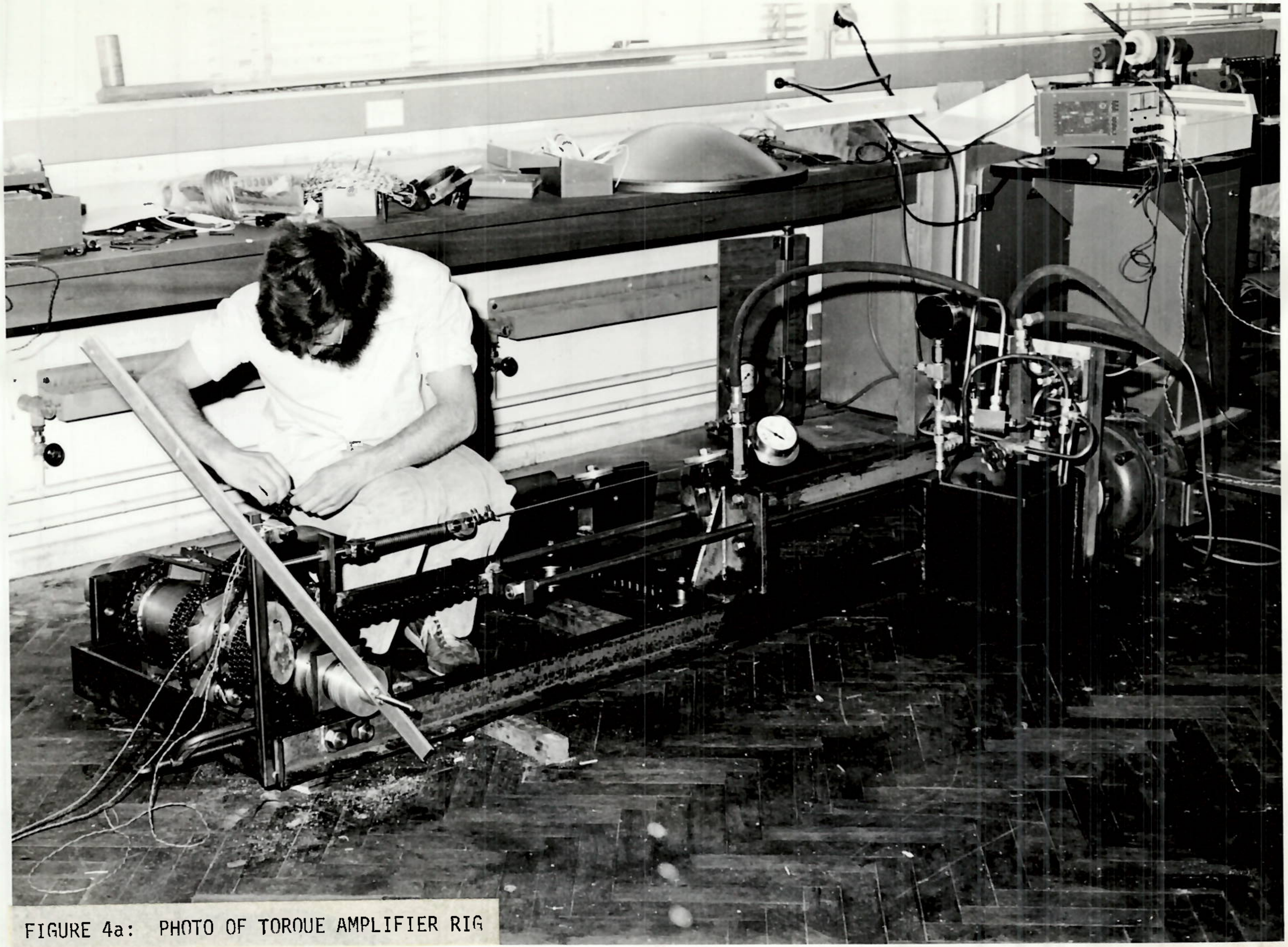


FIGURE 4a: PHOTO OF TORQUE AMPLIFIER RIG

FIGURE 4a: The torque amplifier is tested in a hydraulically operated testing rig. The torque amplifier itself is on the left of the rig: the input angle control arm is on the near side; the load arm on the far side (a heavy steel bar).

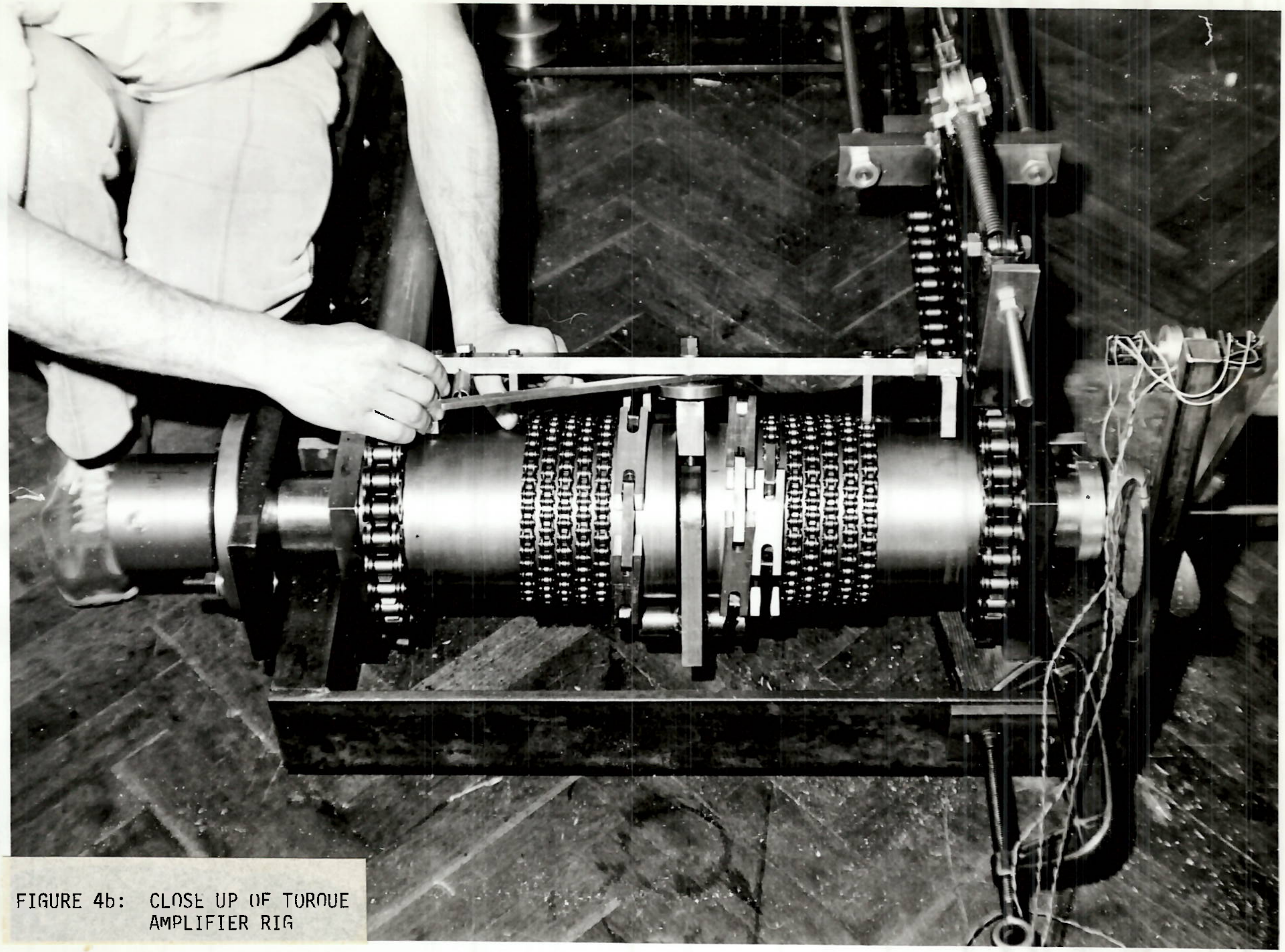
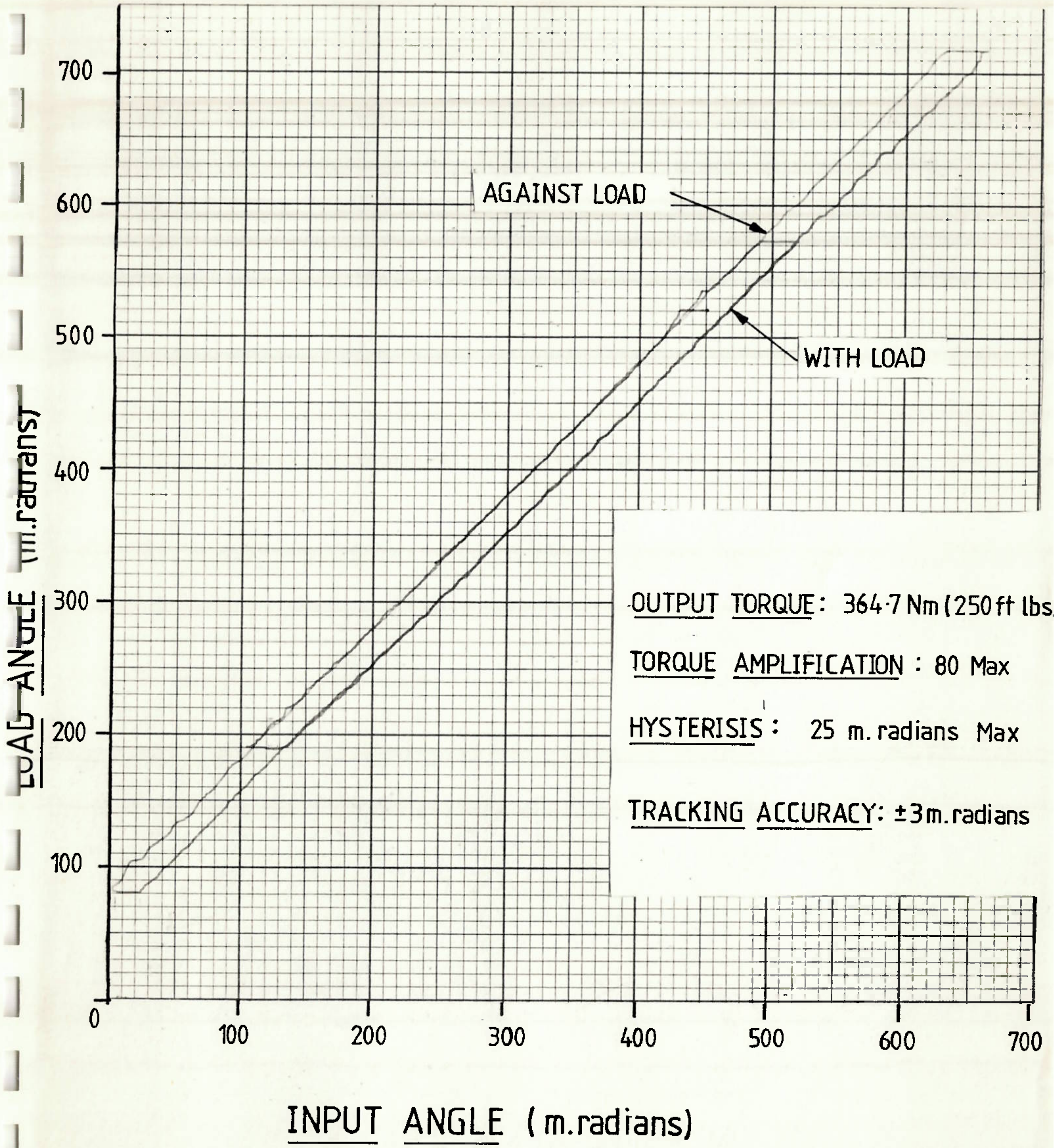


FIGURE 4b: CLOSE UP OF TORQUE AMPLIFIER RIG

FIGURE 4b: The torque amplifier is essentially a set of two contra rotating capstans. The capstan principle is used to amplify the tension in the chains which are attached to the output shaft via a pillar between the drums.



RESULTS OF TORQUE AMPLIFIER TESTS

19th, July, 1979

Fig. 5

The torque amplifier is described in the Energy Conversion Group Report 'A Proposal for the Construction of a Solar Pilot Plant Based on High Temperature (500^{o}C) Shell Mirror Collectors', P O Carden, R E Whelan, K Thomas and R W Parkes, July 1978. Since that report was published the concept has been simplified.

The drawing No C003 details the torque amplifier now being tested. It is shown assembled with its testing rig in Figure 4a. The origin of the output torque is a chain tensioned by a hydraulic ram. The chain passes around two sprockets which rotate in opposite directions. The torque amplifier transfers the torque from either of these sprokets to the output shaft under the control of the relatively small input torque. Both input and output shafts are fitted with potentiometers which provide signals to an X-Y recorder. A bar of steel attached to the output shaft provides static and dynamic loading.

A typical X-Y plot of input shaft angle vs output shaft angle is shown in Figure 5 .

The results of the first two weeks of testing carried out so far are encouraging. The torque amplifier has been tested at full design torque of ± 250 ft lbs and against representative inertial loads. Five turns of chain have been wound on each capstan drum giving torque amplifications up to 80.

Tracking in either direction is accomplished with a maximum following error of 3 mradians, a result which is already almost acceptable. Hysterisis which occurs when the direction of rotation is reversed is 25 mrads.

Further tests are planned with several more turns of chain in order to achieve torque amplifications of the order of 1000.

Several features of the torque amplifier need to be improved. The operation is a little jerky due to stick-slip action and wind-up in the input shaft (most of the observed tracking error is due to this). Application of a lubricant may be a solution to the problem. It is also likely that higher torque amplification may help since the input torque and wind-up will then be less.

Almost all the hysterisis is due to insufficient rigidity of the input mechanism and is practically independent of load. Efforts will be made to improve this by a factor of 10 or more.

If the device proves to be satisfactory it is planned to design a prototype of twice the size and eight times the torque. The design will then be costed and the degree of cost-effectiveness determined.

3.4.2 Conventional Alternatives

A backstop design of actuator is required in order to avoid the actuator being on the critical path of development of the fluid heating system. It is judged that the successful development of the mirrors alone would warrant their testing in a pilot plant without any delay caused by the development of other components.

An actuator employing a harmonic gear train was designed and built several years ago and found to operate satisfactorily. If necessary a scaled up version of this design may be prepared quickly. (Refer to drawing No 1001)

4. SYSTEM DESIGN

The major elements of the system and the status of the design of each is listed in Table I.

TABLE I

ELEMENT	DESIGN STATUS
Collector shell	Design complete. Manufacturing method defined. Costs dependent on the cost and performance of of the vacuum press References: drawing Nos H007 shell, A001 press
Reflective surface	Candidate selected. Manufacturing options under study.
Focal absorber	Computations completed
Collector mounts	Defined sufficiently for cost estimating Reference drawing No H001
Actuators	Torque amplifier under development. Back stop design using harmonic gears defined sufficiently for cost estimating Reference drawing Nos C003 torque amp, I001 backstop
Collector control	Defined sufficiently for cost estimating Reference 3
Fluid reticulation and monitoring	Incomplete

As can be seen from this table the design is well advanced. The major outstanding elements are dependent on the completion of the press, and the completion of the two developmental projects: reflective surface application and torque amplifier.

In the case of the torque amplifier, a more conventional design of actuator is available as a backstop should development take too long. This alternative is an in-house design based on harmonic gear trains and a small scale version of it has been working successfully off and on at our laboratory over a period of several years. The collector mounts referred to in Table I have been designed so that either type of actuator may be fitted.

With regard to the collector mounts the design described in ref 1 has undergone considerable change since publication of that report in July 1978 resulting in the modified design shown in Figure7. The principle changes are listed hereunder:

a. The shell sub-frames are now simple square welded structures sufficiently rigid to render the wire bracing unnecessary.

b. The column is considerably shorter.

c. The gate sub-frame now extends from the bottom of the column as well as the top. The wire bracing has been eliminated.

d. There is only one common elevation actuator shared between the two collectors of a pair.

e. The clamming or stowing actuator is simplified: it now operates between two pre-set stops.

The above modifications were implemented in the expectation that they would result in an overall cost saving. Modifications d and e should contribute to this by eliminating one actuator per pair and simplifying another. However, some of the resulting savings will be cancelled because the modifications require manual adjustment of the stops and extra precision in the manufacture of the frames.

The collector control system has been specified in general terms in ref (2) and is presently being developed according to the plan set out in Figure 6.

The system design originated in the Energy Conversion Group during the past few years (refs (3), (4)) and is based on what is now known as the concept of distributed intelligence (see for example, Scientific American, June 1979, pp 54-66).

- There are two main system control units requiring development: the central control unit (CCU) and the mirror control unit (MCU).

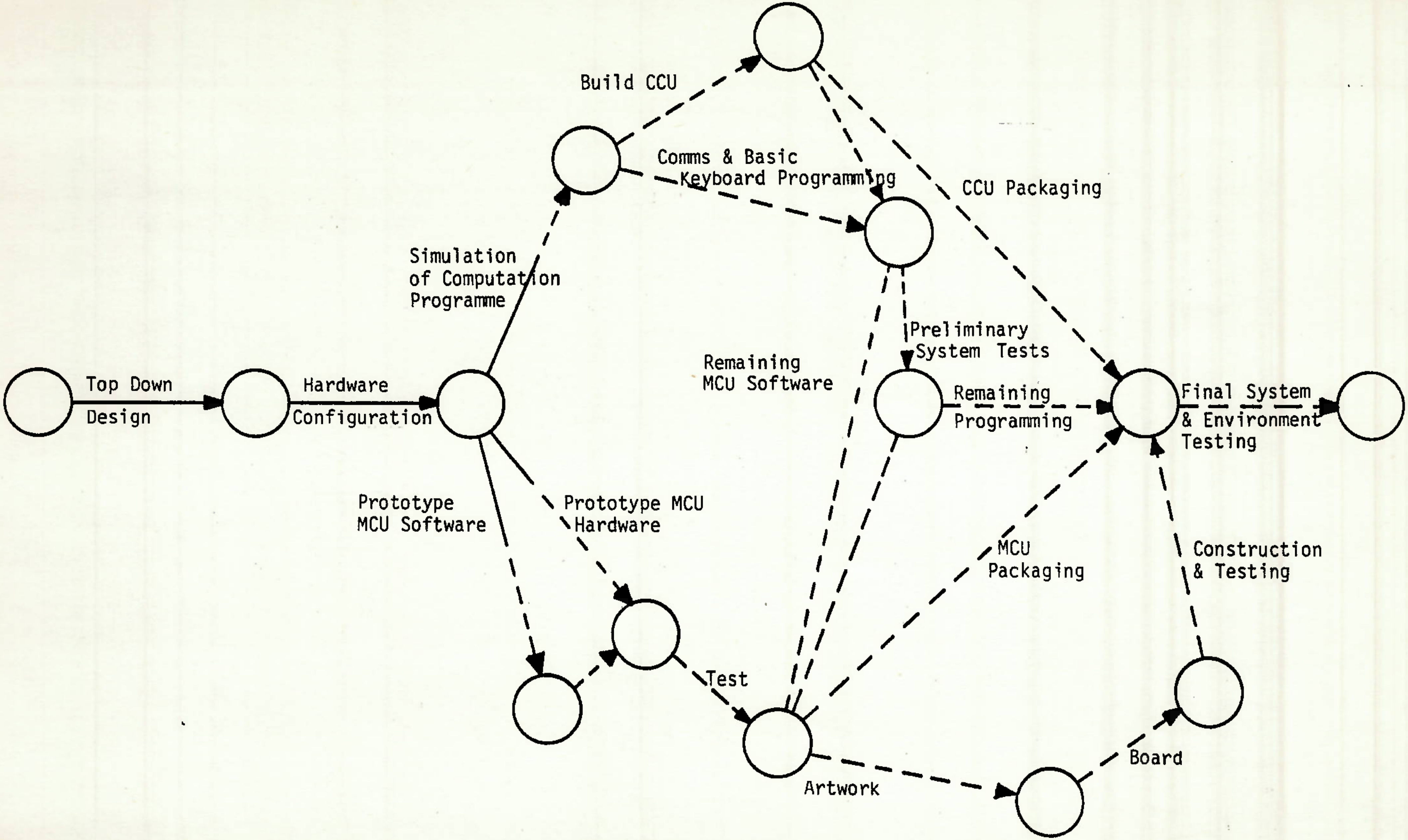
- The CCU is common to all mirror collectors and performs computations for steering, clamming and unclamming.

- Each MCU is a small independent unit associated with a pair or mirror collectors. It provides all the functions necessary for normal operation. In addition it transmits to the CCU the pointing errors determined by the shadow sensing pointing error detectors.

- The control units are interconnected by a digital communications system.

- Each MCU has a unique address. A standard communications protocol is used to enable many MCU's to be connected to one communication line. A differential drive interface is used to give a long distance drive capability.

- Because of the need for reliability, there is provision for a redundancy of communication lines.



DEVELOPMENT CHART

Fig. 6

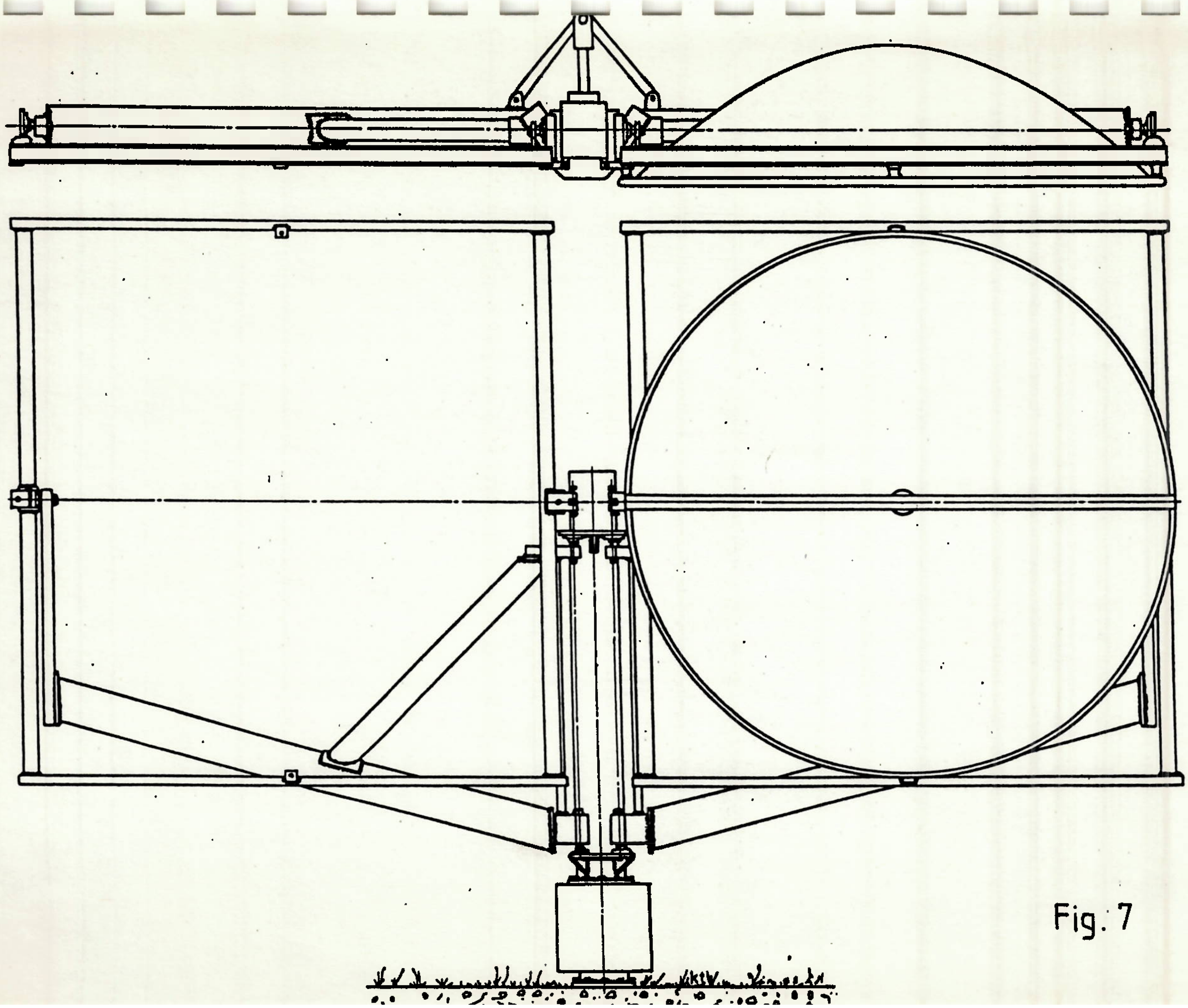


Fig. 7

- Dual power supplies are used to supply the CCU and MCU's.

So far MCU candidate microprocessors have been identified, evaluated and one selected. Two computer programmes have been developed: one accepts the symbolic language appropriate for the selected microprocessor; a second simulates its behaviour. These programmes are now being used to develop the MCU software. A microprocessor has recently been delivered and will be incorporated in a prototype MCU.

A monitoring system will be required for measuring all the quantities necessary for evaluating the thermal efficiency and overall performance of the fluid heating system. Some initial thought was given to the conceptual design of this monitoring system as a result of an offer by the Energy Authority of NSW to contribute $11,000 towards the cost of components. Subsequently, a list of components was prepared where cost approximated that sum. However, an outstanding item not included was a small computer necessary for integrating the equipment into a working system. Although there is no immediate need for the monitoring system to be completed, in the interests of the efficient use of labour, it should be amalgamated with the collector control system and hence both systems now require funding.

5. COST ESTIMATES PREPARED BY CONSULTANTS

5.1 Collector Mounts

The detailed design of the collector mounts has progressed sufficiently to enable cost estimates to be prepared. Dr Carden has met with senior staff of Hawker de Havilland Sydney and through this organisation has secured the services of CCR Engineering of Marrickville. CCR has assisted with engineering advice and has prepared the cost estimates summarised in Table II. Hawker de Havilland themselves expressed considerable interest in the project (refer to the attached letter) but, because their estimators were working overtime on government tenders, felt unable at the time to commit themselves to meeting our timetable.

CCR Engineering have been asked to examine our design, modify it if thought desirable, and prepare cost estimates for the manufacture and erection in Bathurst of (a) a single pair of collectors, (b) two groups of ten pairs of collectors and one group of fifteen.

Estimate (a) therefore represents the high extreme of the expected spectrum. CCR's estimate for (a), which excludes the labour of manufacturing the paraboloids and the cost of the reflective surface, is $19,026. Their estimate for an alternative design which closely parallels the McDonnel Douglas heliostat design (two mirrors mounted on a frame, central pedestal, stowed with mirrors facing the ground) is $16,419. These estimates include fares to and from Bathurst, living expenses, the cost of jigs and fixtures. They are also based on quotations for subcontracted work and therefore include considerable margins for contingencies.

At the time of writing, estimate (b) has not been completed.

The estimates appearing in Item 13 of the present Application for a Support Grant have been based on the estimates prepared by CCR Engineering.

The figures of Table II are disappointingly high and we will be seeking ways to reduce them ultimately by a factor of ten with quantity production. Part of the reason why the estimates are so high is that they refer to an unlikely quantity: one pair of collectors. However the preparation of the estimate for this situation was a necessary first exercise. Other reasons are that the design is still too sophisticated in some respects and the mirror size 10 m^2 is too small.

We do not expect that our consultants will be able to help us a great deal with the design by offering assistance based on a full appreciation of the constraints on cost. Nor are they experts on quantity production. For these reasons we will be seeking additional advice from an organisation such as G.M.H. with whom we have had previous contact.

TABLE II

COST ESTIMATE FOR MANUFACTURE AND ERECTION IN BATHURST OF ONE PAIR OF COLLECTORS

Prepared by CCR Engineering Ltd
Design modified by CCR

Subcontracting	$
Civil works: design, construct footing (4 m^3 in Bathurst)	1,500
Supply of aluminium sheet	512
Weld, grind and cut aluminium sheet into discs (including jigs $400)	1,900
Two aluminium rim stiffening rings	
materials	173
jointing	60
rolling	80
mounting	30
jig	400
Gearboxes	2,700
Cartage including crates	700
Other	1,323
	9,378
Fabrication	
Gearbox mounting, parts	1,500
Materials	2,049
Labour 137 mh at 13 $/mh	2,561
Galvanising including $70 cartage	730
Drawings	500
	7,340
Erection	
3 men for 2 days	2,308
TOTAL (excluding press-forming aluminium and reflective liner)	$19,026

5.2 Collector Control System

The cost of developing the control system has been estimated by NR Pty Ltd of Canberra to be $37,300. This figure is based on 1978 prices for components and labour and does not include a contingency allowance.

6. UNEXPECTED DIFFICULTIES

- The steel rings for the vacuum press have cost more than expected because of difficulties with welding distortion and because, for reasons of industrial safety, two persons are required to operate the boring mill although it is not always possible to keep both productive.

- The contractors have not been able to deliver the cast aluminium segments for the paraboloidal die in the time quoted. These components are now due in early August, three months late. The problem has been distortion.

- Other difficulties have been mentioned in the rest of this report but are comparatively minor and of a nature normally expected in the course of development.

- The moulding of acrylic, wind tests on model collectors and the torque amplifier have all so far turned out to be better than expected.

7. RECOMMENDED FUTURE PROGRAMME

Our future programme must take into account the prospect of a contract from the NSW Government for a 25 kw_e power station. Such a power station has always been part of our integrated programme (refer, for example, to the 1978 application and the present application fig 1) but previously it was to be constructed after the development of the collectors and the installation of a fluid heating system at Bathurst. The contract from the NSW Government should now enable the power station to be installed practically concurrently with the fluid heating plant and in addition enable the development of the collectors to be accelerated. Under the circumstances we submit that it would be appropriate for development of the collectors to be sponsored equally by NERDDC and the NSW Government. While this would not result in a reduction of the annual support requested in the present application, it should substantially reduce the amount of any future application for support for a 25 kw power station. Such support might for example merely cover a research programme based on observations of the performance of the NSW Government power station. It would be expected that the development of larger power stations employing thermochemical energy transfer could be brought forward provided that the chemical heat pipe project were funded sufficiently in the meantime to enable it to keep pace.

Items 12 to 14 of the present application assume that the collector development cost is shared as described. But the cost of the ANU installation and the labour cost of the Bathurst installation have been assumed to be an exclusive charge on NERDDC.

The major stages of development and construction of the collectors are set out sequentially in Figure 8a. The critical path is presently assumed to be via the machining rig (a boring mill attachment for machining a parabolic form). The number shown for each stage is the average number of persons assigned to that stage. Figure 8b is a graph of the total number of persons employed at a given time, the type of person (contract labour, staff, etc) and the source of funding. Figure 8c shows the approximate total expenditure vs time and therefore indicates the expected cash flow requirements.

The total sum anticipated is $500,000 over 21 months.

During this period and with the additional staff requested, it will be possible to do preparatory work specific to the site at Bathurst. After the 21 months have elapsed the NERDDC funded staff would work exclusively for the remainder of the three year period on the fluid heating project and on monitoring the power station.

The cash flow requirements detailed in Section 16 of the application reflect the time scale and the expected level of activity outlined above.

The University intends leasing a building at Fyshwick or Queanbeyan to provide space for the manufacturing and assembly of the collectors.

SEQUENCE OF MAJOR STAGES OF DEVELOPMENT OF COLLECTORS

Showing Number of Persons Required Per Stage

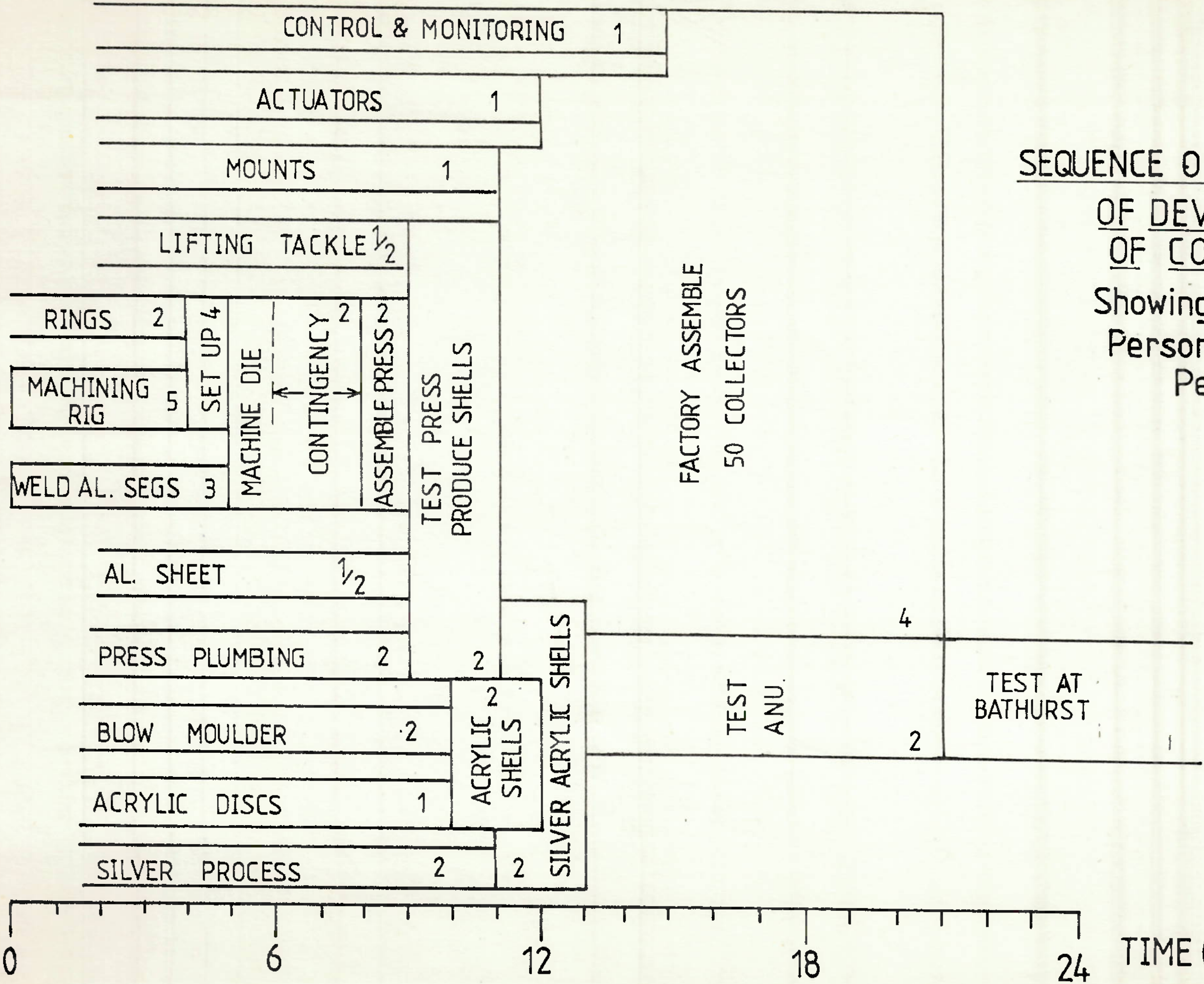


Fig 8 a

ORIGIN & FUNDING OF WORK FORCE

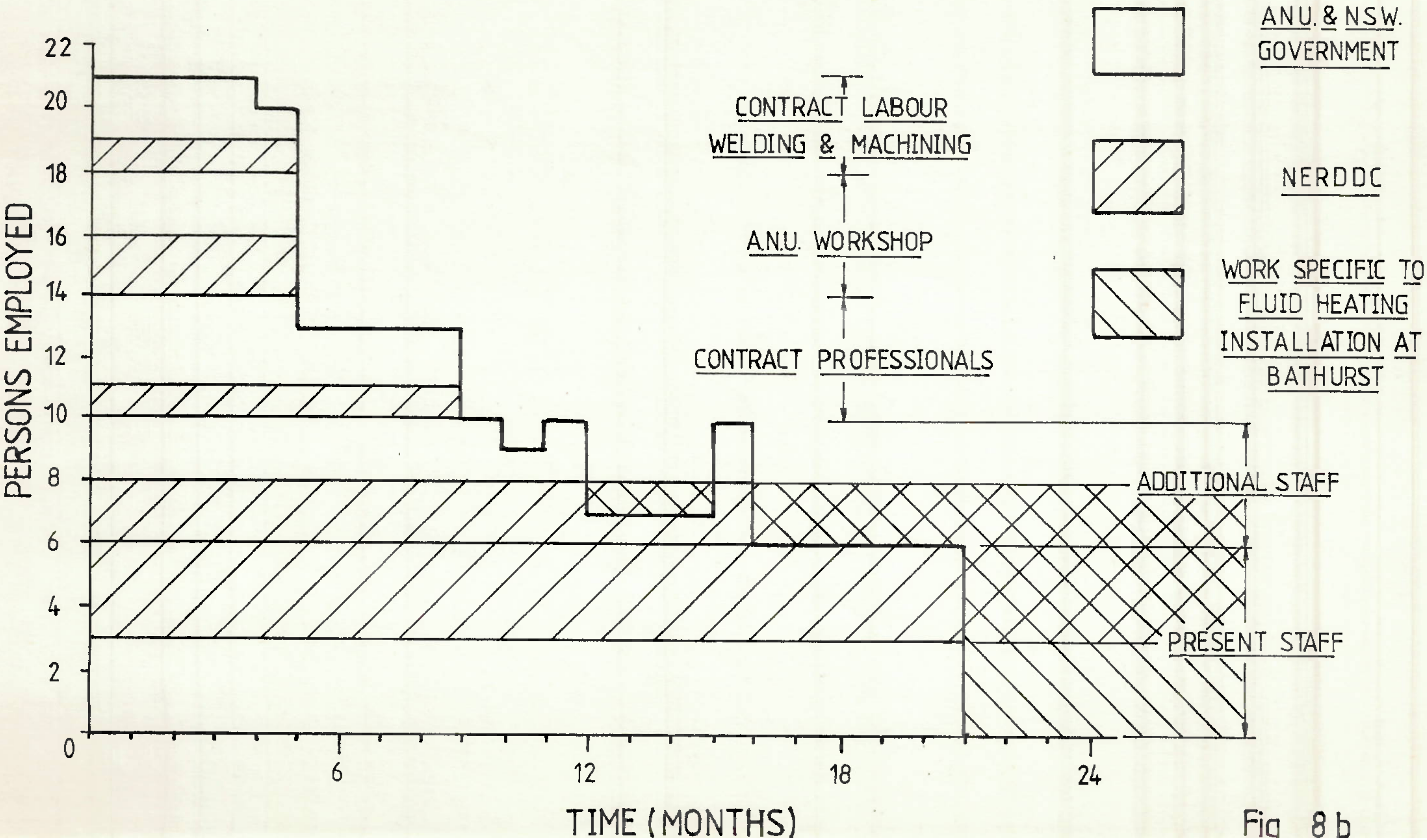


Fig 8 b

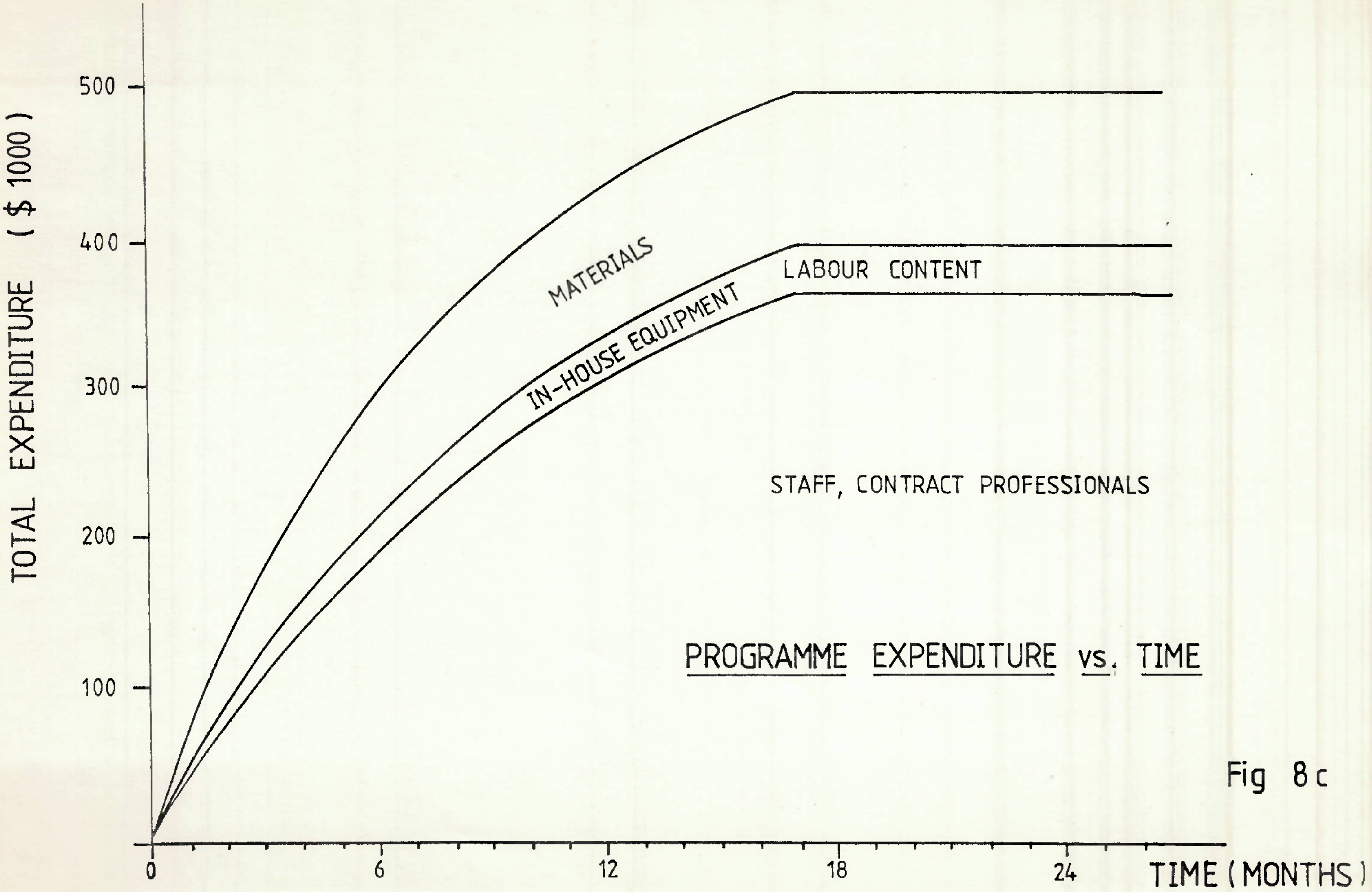

TOTAL EXPENDITURE ($ 1000)
500
400
300
200
100
0
6
12
18
24
TIME (MONTHS)
MATERIALS
IN-HOUSE EQUIPMENT
LABOUR CONTENT
STAFF, CONTRACT PROFESSIONALS
PROGRAMME EXPENDITURE vs. TIME

Fig 8c

8. PATENTS

It is anticipated that patent applications will be made in some or all of the following areas:

a. torque amplifier

b. vacuum press

c. acrylic moulding

d. mirror collector.

9. PUBLICATIONS

The publications of the Energy Conversion Group are attached hereto. None of the work that might be patentable has been published.

10. REFERENCES

1. P O Carden, R E Whelan, K Thomas, R W Parkes, 'A Proposal for the Construction of a Solar Pilot Plant Based on High Temperature 500°C Shell Mirror Collectors', Energy Conversion Group publication, July 1978.

2. P O Carden, 'Orientation Control Systems for Solar Pilot Plant (300°C Liquid Heating)', Energy Conversion Group publication, April 1978.

3. Estimates for the Development of Orientation Control Systems for Solar Power Plant, NR Pty Ltd report, 23 June 1978.

4. B P Edwards, 'Aspects of Arrays of Paraboloidal Collectors for Utilisation of Solar Energy', PhD thesis, Department of Engineering Physics, ANU, March 1979.

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MEMORANDUM

Arising from discussions March 26/79 with Mr. P. Carden (A.N.U. Canberra) Hawker de Havilland confirms the following with respect to Solar Energy Research and Development.

1. H.D.H. have a specific interest in participating in programs related to advanced technology such as Solar Energy Programs.

2. H.D.H. have existing engineering capabilities capable of carrying out mechanical/structural design and manufacture.

3. H.D.H. are interested in participating in a Development Program.

4. H.D.H. are interested (with their worldwide associated companies) in manufacture and marketing of such systems.

SUMMARY: H.D.H. is interested in exploring the above areas.

P.A. Lister
Marketing Manager
HAWKER DE HAVILLAND AUSTRALIA PTY. LIMITED
DATED : 26TH MARCH, 1979