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REPORT ON DUTY AT THE HARTRON IDDC UNIT

AMBALA CANTT, HARYANA, INDIA

by

J. MAXWELL

for

UNIDO VIENNA

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JOB DESCRIPTION

DP/IND/79 046/11-05/31.9.F
Expert in Design Optical Instrumentation

Date of briefing in Delhi - 23 September 1985
Date of starting duty in Ambala - 24 September 1985
Date of finishing duty in Ambala - 17 October 1985
Date of debriefing in Delhi - 1? October 1985

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INTRODUCTION

Ambala is a major, indeed, probably the major centre for the manufacture of optical instruments in India. Because of this, the UNIDO project to establish an Instrument Design and Development Centre is of particular importance to the future of the optical instrument industry in India.

Ambala is an important centre for the manufacture of other types of scientific instruments as well but it is only one among several such centres, so again, the optical activities of IDDC emerge as being of particular significance.

With this background in mind and in view of the specialist optical responsibilities of my job description, I have chosen to write a rather longer report than would normally be prepared on the completion of a one month assignment. I would particularly draw the attention of the reader to Sections 2.7(ii), 2. & 3.10(a), 2. & 3.10(e) and [illegible]

I was impressed with the enthusiasm and dedication of the management and staff of IDDC Ambala, Hartron headquarters in Chandigarh and also those from UNIDO and I would like to take this opportunity of thanking them all for their co-operation and support during my duty period.

This enthusiasm and dedication is an important resource for IDDC and will contribute to the ultimate success of this unit.

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1. OBJECTIVES

1.1 To provide direct training, teaching, collaboration and tutoring to IDDC and local industrial engineers in the area of optical design, engineering and testing.

1.2 To provide technical consultancy support on specific IDDC projects and services.

1.3 To assist IDDC engineers to take up specific projects with local industry and where appropriate to provide direct technical consultancy to local industry.

1.4 To prepare recommendations for the purchase of equipment.

1.5 To prepare recommendations for the provision of future technical support.

1.6 To arrange for training placements for IDDC engineers in the UK through the UNIDO training fellowship programme and to advise on further training requirements.

1.7 To review optical manufacturing activities in Ambala and suggest new projects or products.

1.8 To make recommendations on the staffing of the optical section of IDDC.

1.9 To prepare the basis on which further technical support may be provided to IDDC engineers through continuing contact.

1.10 To review miscellaneous matters which are relevant to the optical work at IDDC Ambala.

2. FINDINGS AND CONCLUSIONS

2.1 a *Lecture-Discussions*

IDDC organises lectures and discussions on an ad hoc basis, inviting lectures from visiting experts who come from both inside and outside India.

These lectures are well organised, well documented and well supported; they are also a valuable forum for ideas and they provide an important stimulus for IDDC engineers and personnel from local industry.

As part of my programme, two lecture-discussions were held at IDDC and a further single lecture-discussion was held at CSIO in Chandigarh as follows :-

i) **Modern trends in optical instrumentation**
(Optics as the servant of detectors, sources and the media)
Date : 30 September 1985 Place : IDDC Ambala
Subject matter : See Appendix 1.
Comment : This lecture was intended to provide an opportunity for me to

level and it did lead to an animated discussion about the direction in which the optical industry in Ambala should develop, a discussion which everyone clearly wished to continue.

ii) <u>The tolerancing of optical instruments</u>

<u>Date</u> : 9 October 1985 <u>Place</u> : CSIO Chandigarh

<u>Attendance</u> : 55 CSIO personnel
3 IODC personnel

<u>Subject matter</u> : See Appendix 1

<u>Comment</u> : This lecture was a presentation of a subject which is of particular interest to me. Fortunately it proved to be of topical interest at CSIO and it led to a lively and detailed technical discussion. It also provided an opportunity for the facilities and skills being developed at IODC to be promoted.

iii) <u>The design of optical instruments including microscopes</u>

<u>Date</u> : 10 October 1985 <u>Place</u> : IODC Ambala

<u>Attendance</u> : 14 from outside industry
8 from IODC

<u>Subject matter</u> : See Appendix 1

<u>Comment</u> : This lecture was intended to be a promotion for the design skills available at IODC, addressed to personnel from local industry. The attendance at this lecture was largely the same as at (i) above and was, again, aimed at a relatively low technical level to stimulate the interest of industrial personnel.

b) <u>Tutorial and workshop sessions on optical lens design</u> with IODC engineers, as follows:-

<u>Estimated contact hours</u> : 16

<u>Attendance</u> : Varying from 1 to 5

<u>Subject matter</u> : See Appendix 2

<u>Comment</u> : This activity was intended to be the major part of my work in Ambala. Due to involvement in other projects I was not able to spend as much time as was desirable on this work. Fortunately, due to the enthusiasm and energy of the IODC engineers involved they were able to start work on a general purpose optical lens analysis program and a small automatic design program for achromatic doublets. In addition, two engineers were able to spend time using the HP85 optical design software. I am confident that this work will continue, and I am also intending to provide continuing support on a postal basis.

IDDC has invested 170,000 US Dollars of UNIDO funding on sophisticated optical thin film coating equipment. So far, IDDC has not developed an adequate software-based thin film design capability to match this facility.

This collaborative work was based on the implementation of published software on computing facilities available with IDDC.

This work will continue on a postal basis.

d) <u>Optical Design and Calculation</u>

The design of optical systems requires a peculiarly intensive use of computing facilities. The present optical computing facilities consist of one HP85 micro computer, with dedicated optical design software and two Apple computers which as yet do not have any optical design software. As there are many other tasks at IDDC which require computer access it is vital that additional computing facilities are provided so that the optical section has <u>exclusive</u> access to a microcomputer with a VDU and printer. This is the absolute minimum of computing facilities that are appropriate for a serious optical design group. As it is likely that local industries in Ambala will want to make increasing use of the optical design service that IDDC can offer I believe that at least two such optically dedicated computers should be provided for exclusive optical design use in the immediate future.

2.2 a) <u>Precision Optical Windows</u>

IDDC has a project to grind and polish a quantity of 3 off 375mm diameter and 2 off 450 mm diameter precision optical windows.

This is a major optical fabrication project and I have spent approximately six working days providing technical support to the engineers working on this project.

The facilities provided at IDDC are at present quite inadequate to meet the technical requirements of this project.

If enough resources are marshalled to complete this project successfully it will be a source of pride, satisfaction and political success for IDDC.

If inadequate resources are provided the project will be a failure and it will be a source of political and technical frustration.

Appendix 3 gives further details of this project.

on imported Balzers equipment has overshadowed the work that may be done with more modest indigenous equipment.

I have spent approximately two working days encouraging the development of a low cost process for the anti-reflection coating of production quantities of prisms and lenses.

This alternative, low-cost technique is important as an activity which is supplementary to the highly sophisticated work that can be done on the Balzers plant. Local industry can easily copy this technology, which is vital if the export potential for Ambala optics is to be realised.

Appendix 4 gives the details of this process.

2.3 <u>Contacts with local industry</u>

IDDC was approached by eight local industries while I was there; each one was interested in developing one or more products of economic importance. I was impressed with the economic potential of these products and the motivation and competence of the industrialists concerned. Several of the companies have a proven export record and are clearly capable of impressive international economic performance. Yet other companies are struggling with very limited resources to try to establish themselves. IDDC has an important role to play in servicing the needs of this wide range of enterprise.

The companies concerned and their product interests are given in Appendix 5.

2.4 <u>Equipment Procurement</u>

Appendix 6 gives a list of equipment that should be purchased by IDDC. That list is not complete: it merely lists some items that are vital if IDDC is to function as a technical resource centre for optics.

2.5 <u>Future technical support required for IDDC</u>

a) <u>Optical Glassworking</u>

Ambala industry and IDDC has, together, a wealth of experience in the manufacture of lenses for microscopes and other small diameter instruments. There does not appear to be any expertise in the working of medium and large diameter optical parts. If Ambala industry is to diversify and consolidate its position, expertise [illegible]

b) Optical Design

Although promising work has been started on the development of optical design services there is scope for the further employment of external consultants to provide tuition and moral support for the development of this work.

c) Optical thin film design and process development

See 2.1(c) above. There is a need for a consultant to be brought from outside to assist in the development of the theoretical designs and the detailed practical processes involved in the deposition of multiple layer thin film devices. Although the Balzers company will provide process packages, it is important that IODC develops some independence in these matters.

2.6 a) Training placements for IODC engineers in the UK

Prior to my arrival in IODC I approached approximately 30 companies and institutes in the United Kingdom to locate appropriate training places for IODC engineers.

This exercise has so far resulted in firm offers from five establishments with a likely additional two establishments willing to co-operate. These offers could accommodate six engineers but due to the resignation of two IODC engineers, and the choice of a further engineer to take up a place in the USA it has been necessary to substitute two alternative engineers and I now have to try and negotiate two more places for engineers who are likely to be cleared in the near future for training with UNIDO and the Indian Government.

Appendix 7 details the current situation on this scheme.

b) Other training needs

UNIDO training fellowships have been offered to technical staff of the engineer grade. There is a need for additional external and/or internal training to be provided for IODC technicians and technical assistants in the optical section. This training requirement is particularly vital for the vacuum coating and glass polishing work where new ambitious projects are being embarked upon.

2.7 New projects and products for Ambala Optical Industries

[illegible]

- i) Microscope systems: Phase contract, Interference, Polarographic, Fluorescent, Metallographic, Planographic objectives, and Apochromatic objectives.

- ii) Other products based on optical technology: Binoculars, Telescopes, CCTV lenses and cameras, Engineering profile projectors and thin film devices (filters, specialised mirrors and anti-reflection coatings).

- iii) In the longer term, Ambala industry and IDDC should aim to compete directly in world markets for the design, development and manufacture of more sophisticated optical equipment. There is currently a healthy international climate for the development of optical devices, which is based on a massive worldwide expansion of computer controlled laser scanning and switching devices, television video equipment, phototypesetting technology and holography. This market expansion has created a shortage of optical resources which IDDC and Ambala industry should aim to benefit from.

2.8 The staffing of the optical section of IDDC

In view of the situation outlined in 2.10(a) below, particularly with regard to the departure of engineering staff for other employment and the preoccupation of key senior engineers with managerial and administrative tasks, it is vital that the situation in the optical section be reviewed with due regard to two basic requirements, as follows:

- i) There must be the freedom for senior engineers to guide, motivate and manage junior colleagues in their technical work. This requires that the senior engineers have additional administrative and clerical support to minimise the time that they have to spend on non-technical activities.

- ii) The optical thin-film vacuum coating workshop staff, consisting of one technician, one helper and one deputed junior engineer, are fully occupied running the existing vacuum equipment. The commissioning and efficient use of the new equipment will be a significantly more demanding technical task, which will absorb their resources fully and require the appointment of additional technical staff. The additional technical staff required for this vacuum coating work will be necessary to run the new equipment efficiently and also to continue the work on the existing equipment, which should not be neglected in view of its economic importance to local industry.

2.9 Preparation of the basis for continuing support

[illegible]

2.10 Miscellaneous matters which are relevant to the optical work at IDDC Ambala

a) The optical work at IDDC

This work is approaching a period of crisis. Two junior engineers are resigning. Three more are departing for six months training overseas. The deputy project director, Dr Jagpal Singh, is heavily loaded with administrative work. Mr Rajesh Rampal is completely occupied with the commissioning of the Balzers equipment and finally, the optical glassworking group has a major optical fabrication project which it cannot be expected to cope with under the present circumstances.

It is vital that managerial attention is focussed on this crisis situation and that additional resources are made available to bridge the resource gap which will exist over the next one year.

The optical side of the work at IDDC is significantly retarded in comparison with the other work in the electronics-based technologies, in view of the optical bias that exists in the industrial activities of Ambala. This is unfortunate and every effort should be made to improve, consolidate and strengthen the optical services that IDDC provides.

b) The mechanical drawing office and mechanical design services

These services at IDDC should be given greater prestige and resource. The personnel should be given training opportunities so that they may apprecia' the requirements of the mechanical design of optical instruments. In particular it is part of IDDC's work to develop products and processes which may then be transferred to external companies. A competent and authorative drawing office is a vital link in this chain.

c) The environmental condition of the mechanical engraving department

The mechanical engraving department is damp. This has resulted in serious damage to the instruments in this department in the form of rust.

There is also a very valuable toolroom microscope in a state of disrepair in this department.

d. Cleaning Services

in the case of vacuum thin film work, where dust can completely nullify the efficiency of the manufactured devices. In India, the difficulty of keeping working machines and workshops clean is compounded by the prejudice that is associated with the work of cleaning. Although I know the workshop layout at IODC is under review the cleanliness of the working environment is not at present adequate and plans should be made to provide special cleaning services for the new optical section to guarantee adequate cleanliness.

e   <u>The Quality Marking Centre and Export House facilities</u>

The Existing Quality Marking and Export House services of the Haryana State Government would appear to be a valuable initiative which can be of considerable economic importance to the optical industry in India.

Although the Quality Marking Centre is, I believe, supposed to be integrated with IODC, and I presume that the Export House service exists and also works with IODC, I became aware that these services are effectively separate and are apparently not practically subject to UNIDO and/or IODC management. This appears to have given rise to a psychological division between IODC and the Quality Marking Centre and Export House with a lowering of morale among the latter organisation's employees.

<u>The siting of optical and mechanical activities</u>

The completion of the new IODC headquarters building offers the opportunity for improved space facilities for the optical section of IODC. It is however absolutely vital that the optical computing, mechanical design, optical fabrication, vacuum coating and testing facilities, along with the fine-mechanical workshops remain as an integrated unit if serious optical development work is to be successful. As it is inconceivable that the new Balzers vacuum coating could be re-sited and as there are several other pieces of key capital equipment which will not benefit from re-siting, it would seem to be obvious that the present site on Staff Road should be retained as the centre for all the optical work.

3. SPECIFIC RECOMMENDATIONS

3.1   a   <u>Lecture-discussions</u>

i) Strategic product planning

Continue and formalise discussions about the type of products Ambala industry should manufacture in the future.

Perhaps a good way to do this would be to prepare descriptive specifications for new instrument products with an assessment of their market potential. This product document could be circulated to potential manufacturers and customers with a request for additional comment and specification information.

ii) CSIO Chandigarh

Maintain contacts with the optical department at CSIO in Chandigarh.

iii) Industrial Optical Design "Workshops"

Provide optical design "workshops" for engineers from local industry, care being taken to match the level to the requirements.

b) Internal Optical Design "Workshops"

Senior IDDC engineers should provide regular, structured and carefully planned optical design workshops for junior engineers and technicians. Because these sessions are for internal consumption, it is easy for them to become irregular and prone to displacement by other activities: this tendency should be avoided.

c) Optical Thin Film Design

Continue with the development of IDDC thin film design software.

The following thin film specialists have developed successful software for the design of this film devices:-

Dr John Seeley,
Department of Applied Physics,
University of Reading,
White Knights Park,
Reading. U.K.

Dr Heather Lydell,
Queen Mary College,
University of London,
Mile End Road,
London, E.1. U.K.

Dr Phillip Baumeister,
Physics Department,
University of Rochester,
Rochester,
New York State,
U.S.A.

Dr H.A. Macleod,
Optical Sciences Center,
University of Arizona,
Tucson,
Arizona,
U.S.A.

d) <u>Optical design and calculation</u>

Buy two more 4045 [illegible] use in the optics department.

3.2. a) <u>Precision Optical Windows</u>

See the recommendations in Appendix 3.

b) <u>Vacuum coating using indigenous equipment</u>

Improve the support for the work that is being done on this equipment.

Approach the manufacturers of the existing vacuum coating equipment with a view to collaboration on the improvement of their equipment for use in optical thin film preparation.

Purchase silicone oil for the diffusion pump on this equipment and maintain a regular supply as required - organic oils are quite unsuitable for optical coating.

Approach the appropriate government chemical laboratory with a proposal that they develop a silicon vacuum oil suitable for optical vacuum coating equipment as an import substitution product.

Review the manufacturers of vacuum equipment in India with a view to purchasing an additional indigenous plant.

Approach indigenous suppliers of vacuum coating equipment with a proposal that IODC develop an optical monitoring system to be manufactured under licence. The work that Dr Butosov did at IODC in February 1985 provides a starting point for this work.

Implement the proposals of Appendix 4 as a supplementary process to that developed by Dr Butosov.

3.3 <u>Contacts with local industry</u>

Follow up the contacts listed in Appendix 5 and review the projects as potential IODC activities. appoint an industrial contact officer for each project. The first task of the industrial contact officer on each project is to make an assessment of the resources required to successfully complete the work in each case.

[illegible]

"cold storage": there is no harm in this and industrialists should be encouraged to be patient.

3.4 Equipment Procurement

Finalise priorities for equipment procurement based on known budgetary provision.

Write detailed procurement specifications for the equipment and circulate to suppliers for final quotations.

Submit quoted prices to the funding authority in the project proposal documents.

3.5 a) Optical Glassworking

Circulate establishments with a proven track-record in manufacturing optical parts with a view to inviting named optical production engineers to visit IODC on short or long-term consultancy agreements. (See also 3.6(b) below.)

See Appendix 3 para 2.5 for three contact names who should be asked to provide additional contacts.

b) Optical Design

Repeat the exercise of 3.5 a) but for optical design expertise. Suitable contacts are as follows:-

i) Dr K.D. Sharma IODC at IIT Delhi	ii) Dr Murty CSIO Chandigarh
iii) Dr Angenailoo IIT Madras	iv) Dr D.V.B. Rao ISRO Bangalore

The best optical design training is however to be found in the challenge of designing specific, needed, optical devices. IODC is in an ideal position to obtain contracts from local industry for the design of such devices. If an IODC engineer has a specific project he will be in a much better position to make use of visiting consultants or to phrase specific, relevant questions in postal questionnaires.

c) Optical Thin Film design and development

Repeat the exercise of 3.5(a) but for (i) thin film stack design, and (ii) practical coating stack process development.

If a consultant can be found who has experience in both these areas it will be found that they are much more useful than either purely practical or purely theoretical engineers.

3.6 (a) <u>UNIDO training fellowships</u>

For future reference, it is vital that the selection of training places and the finalisation of specific training arrangements for named candidates is co-ordinated with greater attention to the needs of the host training establishment. The conflicting co-ordinational activities of IDDC/UNIDO, IDDC/Hartron, UNIDO Vienna, British Council, UNIDO expert in host country and the host training establishment itself produce an impossible situation for potential hosts.

The present arrangements should be finalised as soon as possible. (See Appendix [illegible].)

(b) <u>Other training needs</u>

Approach U.P. State Observatory glass workshops, Nainital with a view to them providing training facilities for Shri [illegible] in the immediate future. THIS ACTION IS OF THE UTMOST IMPORTANCE IF THE PROJECT OUTLINED IN APPENDIX [illegible] IS TO SUCCEED.

Approach thin film coating establishments in India and overseas with a view to securing practical training in multiple layer thin film coating for Shri Ravinder Kumar. THIS ACTION IS OF THE UTMOST IMPORTANCE IF THE "BALZERS" PROJECT IS TO SUCCEED.

3.7 <u>New Projects and Products</u>

See sections 3.1(a)(i) and 3.3 above.

3.8 (i) <u>Staff of the optical department of IDDC</u>

Recruit an administrative assistant to relieve senior engineers of non-technical administrative duties and to provide supporting co-ordinating consultancy services for local industry.

(ii) Recruit two additional vacuum coating technicians.

Dr Buttson	Mr J. Maxwell	Dr K.D. Sharma
Dr M. De	Dr J. Bates	Dr [illegible]

This contact should [illegible] take place in the context of a project which is of particular interest to the specific consultant. The postal contact should be maintained by an individual engineer who is involved with the project concerned.

3.10 Miscellaneous Matters

3.10 a) The optical work at IDDC

The management team of IDDC/Hartron should formulate a plan to cope with the crisis situation that will exist over the next one year in the optical section at IDDC. The key features of this plan should be:-

i) Provision of adequate resources to cover the needs of the Balzers commissioning project and the large plane parallel windows project. These are commitments that already exist with IDDC and which must be given the highest priority.

ii) Identification of priorities for tasks not covered by (i) above.

iii) Provision for the issue of a formal statement to local industry about the nature of the short-term resource crisis in the optical section. This statement can be published in the IDDC Newsletter.

iv) Preparation of a brochure advertising the optical services of IDDC. The issuing of this brochure should be timed to precede the return to full strength of the optical section.

v) Implementation of the recommendations at 3.8 above.

b) Mechanical Design and Draughting

Arrange internal and external training courses for IDDC mechanical design personnel. These training courses should include opportunities for the participants to learn about optics and optical instruments.

MIRA Institute in the U.K. organises specialist courses for mechanical engineers [illegible]

[illegible] establishments who are prepared to provide training facilities. Suitable Indian establishments which have optical know-how are:-

CSIO Chandigarh

Ordnance Factory and
IRDE Dehra Dun

NIL Calcutta

[illegible] Machilipatnam

[illegible] Delhi

[illegible] Ahmedabad

ISRO Bangalore

c) Environmental condition of the mechanical engraving department

It is a matter of the highest priority that the source of humidity in this area, namely the soil that is covering the damp-proof course, be removed; the machines cleaned, serviced and recalibrated, and the air-conditioning reconditioned.

d) Cleaning Services

Recruit or appoint a cleaning supervisor who appreciates the importance of providing adequate cleaning services.

Provide special allowances for cleaners who work in the optical section so that they can be put under pressure to provide improved services and so that they may also be expected to clean machines and workshops.

e) The Quality Marking Centre and Export House facilities

It would seem to be sensible to complete the integration of these services into the IDDC structure, in that they offer a perfectly complementary service to the technical activities that IDDC has been concentrating on.

Such a complete integration may create a further reduction in morale for the Quality Marking Centre and Export House personnel and it is the responsibility of Hartron management to avoid such a situation developing.

f) The siting of the optical and mechanical activities

Review the existing plans for the colonisation of the new Hartron building in Ambala and reconsider any plan which involves re-siting any optical activities [illegible]

LECTURE - DISCUSSIONS

MODERN TRENDS IN OPTICAL INSTRUMENTATION

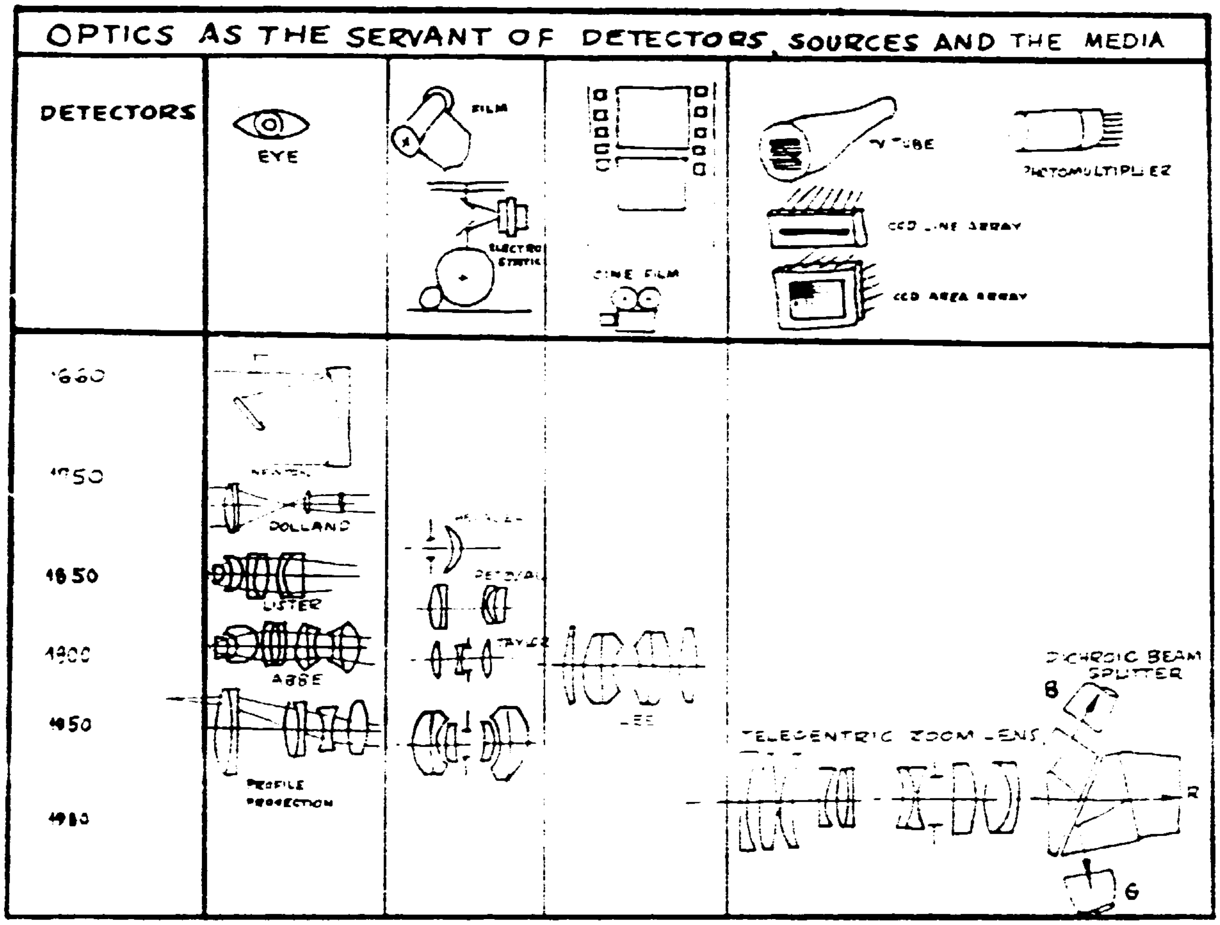
Optics as the servant of detectors, sources and the media.

The development of optical systems has followed the development of detectors (see diagrams). The eye was the detector that gave rise to the telescope and microscope, both of which are characterised by narrow fields of view. The photographic film stimulated wide field camera lenses. The cine camera stimulated the development of wide field, wide aperture camera lenses. Television has stimulated the development of zoom lenses with wide zoom ranges and wide apertures.

Similarly, the development of optical systems has followed the development of light sources. The sun, incandescent sources, gas discharge sources, light emitting diodes and lasers have all given rise to their own families of optical systems as illustrated in the diagram.

Workers and managers, salesmen and engineers, proprietors and financiers, all those who live by manufacturing optical instruments owe it to themselves and their colleagues, families and communities to be aware of these trends and anticipate new applications for their products and skills. Only in this way can they survive and prosper.

If we look at some modern applications of optics (see diagrams) we see that the old sources and detectors still play a part (the eye, film, incandescent lamps), but they are often now part of much more complex systems than previously and they are supplemented by more recently developed sources and detectors (lasers, photomultipliers, TV tubes).


OPTICS AS THE SERVANT OF DETECTORS, SOURCES AND THE MEDIA
DETECTORS
EYE
FILM
CINE FILM
TV TUBE
PHOTOMULTIPLIER
CCD LINE ARRAY
CCD AREA ARRAY
1660
1750
1850
1900
1950
1980
DOLLAND
LISTER
ABBE
PROFILE PROJECTION
TELECENTRIC ZOOM LENS
DICHROIC BEAM SPLITTER
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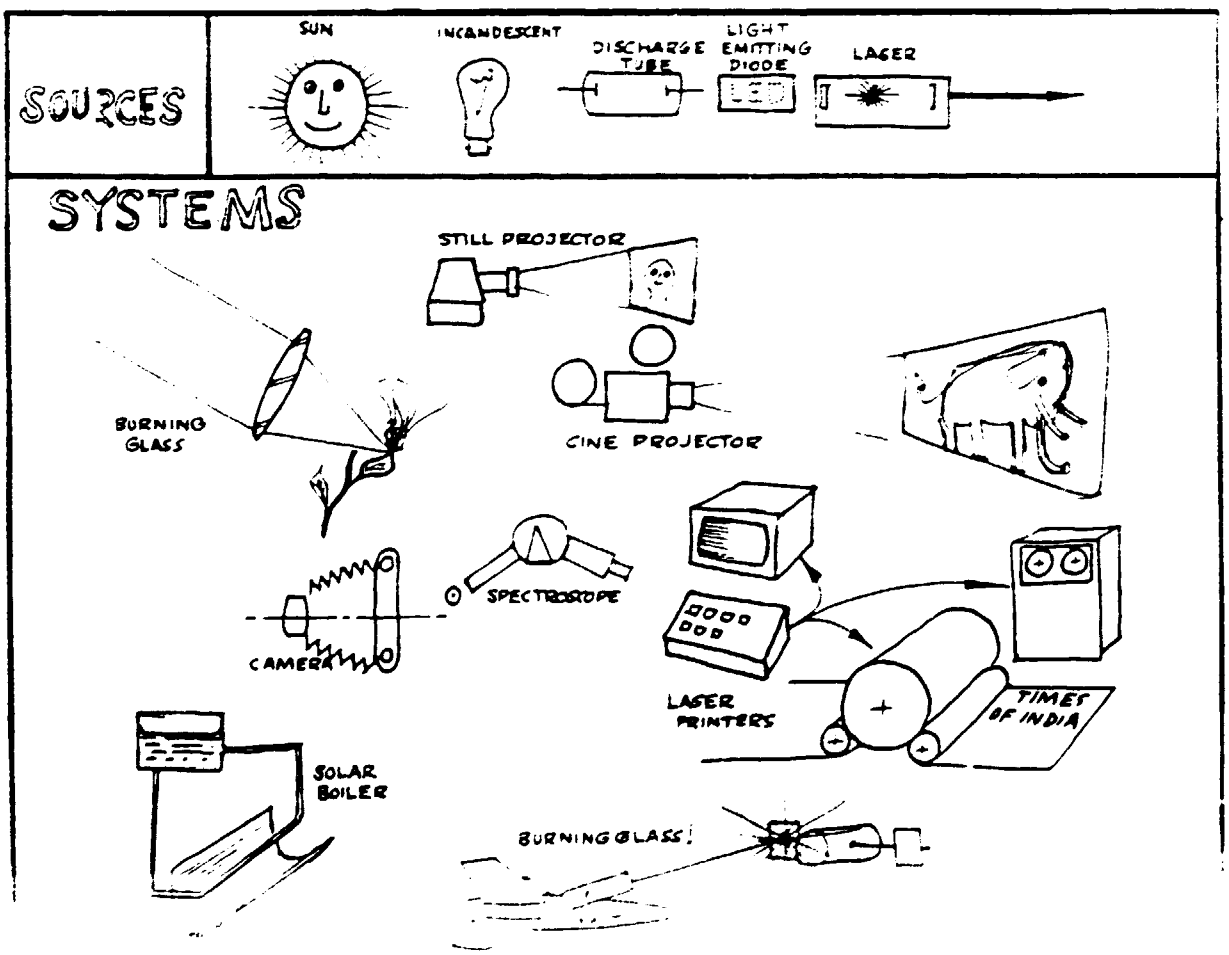
SOURCES
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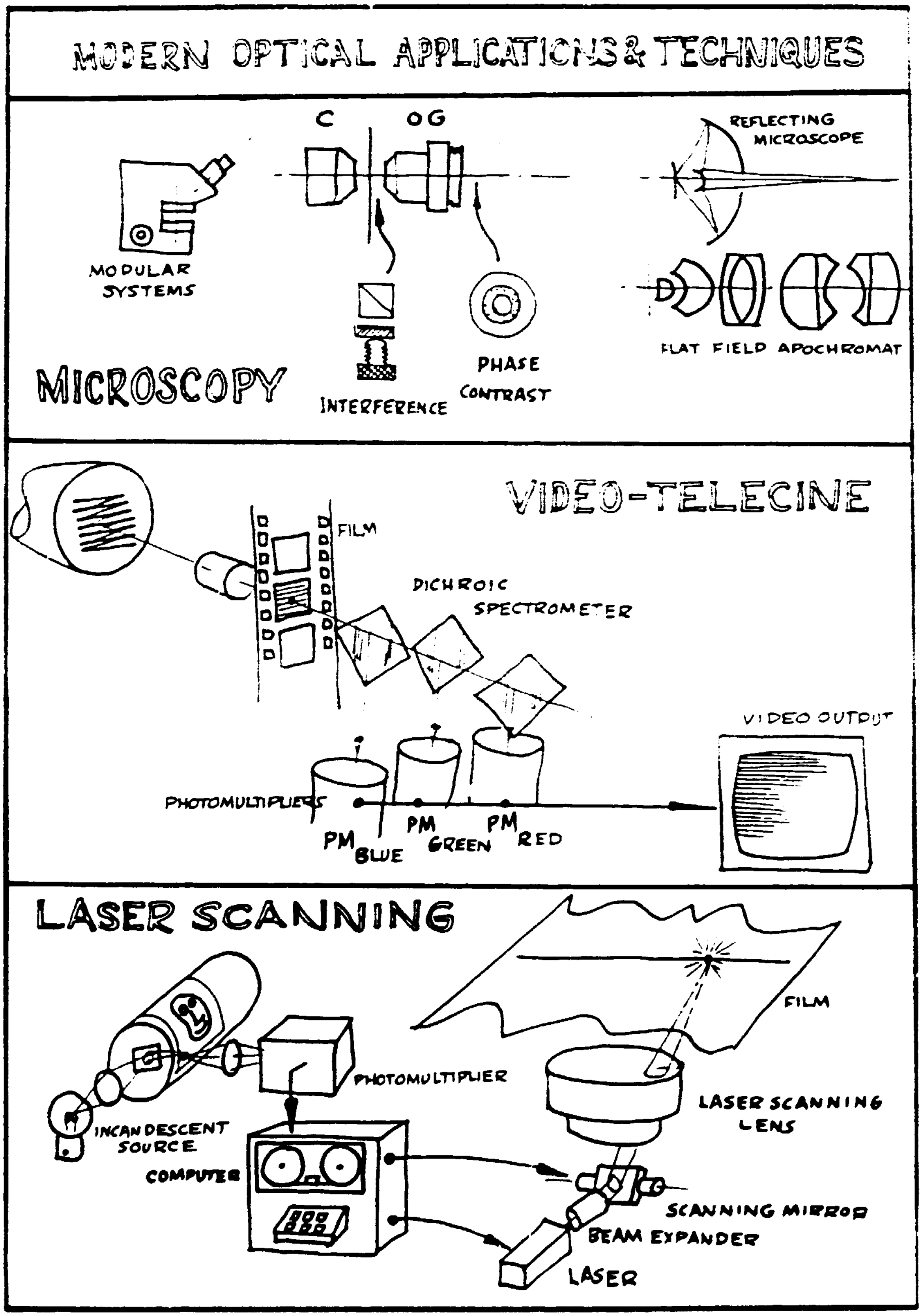
CAMERA
LASER PRINTERS
TIMES OF INDIA
SOLAR BOILER
BURNING GLASS!


MODERN OPTICAL APPLICATIONS & TECHNIQUES
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OG
REFLECTING MICROSCOPE
MODULAR SYSTEMS
INTERFERENCE
PHASE CONTRAST
FLAT FIELD APOCHROMAT
MICROSCOPY
VIDEO-TELECINE
FILM
DICHROIC SPECTROMETER
VIDEO OUTPUT
PHOTOMULTIPLIERS
PM BLUE
PM GREEN
PM RED
LASER SCANNING
FILM
PHOTOMULTIPLIER
INCANDESCENT SOURCE
COMPUTER
LASER SCANNING LENS
SCANNING MIRROR
BEAM EXPANDER
LASER

THE TOLERANCING OF OPTICAL INSTRUMENTS

Introduction

The design and manufacture of optical instruments is a commercial activity and optical and mechanical designers have a responsibility not only for the theoretical performance of the systems they design, but also for the profitability of the product. Nowhere is this wider design responsibility more acutely felt than in the area of tolerancing.

Carefully computed tolerances, expressed in appropriate terms, applied to every manufactured feature and balanced in collaboration with the production engineers involved, are the keystone of profitability, productivity and high morale. Such tolerances release manufacturing resources from easy manufacturing operations and allow them to be applied where they are required in difficult manufacturing operations.

Historically, very little optical tolerancing was done because the computational power was not readily available; now it is, it still requires careful use to generate sensible tolerances, and to avoid being swamped with data.

There are many different types of optical tolerancing situations, each requiring a different treatment. Similarly, there are many different views of how to deal with the data, or which features to concentrate on while tolerancing, so it is not easy to present a simple straight-forward account of how optical tolerancing is done. This is particularly true of tolerances for asymmetric manufacturing errors, but it is precisely this area that is so important to clarify, so that reliable, unambiguous tolerances may be generated.

For the purpose of describing the problem, we will consider a typical photographic type of optical system corrected for field curvature and astigmatism (an anastigmat) and discuss the effects of asymmetric manufacturing errors.

For such an optical system we can calculate or measure the modulation of the image (the contrast) for a particular strategic spatial frequency at a range of focal planes across the image field, and so plot the curves shown at the top of Fig. 1. These show the best focus surfaces with their focal scale, so that the peaks of the through-focus curves correspond to the points marked on the field surface curves above.

As far as tolerancing is concerned it is the health of the focal window that is important. The two limiting through focus curves should cross at as high a modulation as possible, and any of the manufacturing errors illustrated at 1 to 5 reduce the area of the focal window and the height of its maximum point. This happens because each of the through-focus curves split into two, corresponding to the two different (asymmetric) sides of the field, or because the off axis through-focus peaks shift due to field curvature.

Consideration of the focal window allows one to decide on a tolerable level for whichever of the 5 aberrations shown is most sensitive, or whichever has the strongest influence on the focal window.

Frequently in anastigmatic lenses, where field curvature is controlled by glass melt monitoring and relatively straight forward separation and thickness tolerancing, and where axial coma is less sensitive than field tilt and field wedge, it is these latter two that limit the performance, and the tolerancing procedure reduces to defining what is a tolerable level of field tilt, and of field wedge and then applying the allowance budget equations given below in section 3.

2. The Anatomy of the Modulation (Contrast) Transfer Function

The curves shown in fig. 1 are the variation of image contrast with focal position for a particular spatial frequency and the loci of the peaks of these curves across the field of view, which are the field curves showing astigmatism and field curvature. These curves are particularly important because they show how much focussing error there is for each point in the field of view and how much astigmatism, that is, the difference between the focal error for radial (sagittal) image detail and tangential image detail.

The more familiar Modulation Transfer Function curve that we find in text books is the variation of modulation (contrast) with spatial frequency at a particular point in the field of view and at a particular focal position. [illegible]

3. Statistical Effects in Tolerancing Optical Systems

The purpose of tolerancing calculations is to determine an allowance of image performance characteristic for each contributory source of error. So if a stack of components is made up from n pieces, and if the tolerance on the stack length is E, an obvious value for the allowance to be allocated to each individual component will be

$$\text{Individual component error allowance} = \frac{E}{n}$$

In the case of a few mechanical components E would be a length error, and $\frac{E}{n}$ would just be the length tolerance for each individual component.

In the case of optical systems however there are three important differences to be considered:

1) E will be something like a spherical aberration error or a field tilt.
2) n will be rather large (typically 10 or more).
3) In the case of surface tilts and decentrations the errors occur at a range of azimuths, i.e. the errors are vectorial and not scalar.

The importance of the first difference is that because the tolerance required on the individual component is to be expressed as, say, a length error and the image characteristic of importance has some other significance, we have to know the value of the ratio between component error and final image error. So for example, if its spherical aberration that is the sensitive image parameter and the thickness of the first glass component of the system is the feature that has to be toleranced, we have to calculate the ("partial differential coefficient") ratio:

$$D = \frac{\Delta \text{ Spherical Aberration}}{\Delta \text{ Thickness of First Lens}}$$

where Δ stands for "change in". From this we can calculate a tolerance for the thickness of the first lens if we have an allowance of spherical aberration to allocate, because

$$\text{Tolerance} = \Delta \text{ Thickness of First Lens} = \frac{\text{Spherical Aberration Allowance}}{D}$$

The importance of the second and third points is that it is very unlikely that all the various sources of error in an optical system would be wrong in the same direction and by the maximum permissable amount, so we can allow considerably more image error per contribution than $\frac{E}{n}$ and a reasonable value is $\frac{E}{\sqrt{n}}$ for symmetric image errors

Symmetric Image Errors

It is normally assumed that a probable summation of errors will take the form

$$E = \sqrt{e_1^2 + e_2^2 + e_3^2 + \ldots\ldots\ldots\ldots e_n^2}$$

If each of the individual contributions e_i has an approximately rectangular frequency distribution there will be a 90% probability that the assembly will lie within the central $\pm\frac{1}{\sqrt{n}}$th of the total possible range. Such a frequency distribution might result from a tight tolerance applied to a feature which is difficult to control in manufacture, followed by 100% inspection, as shown in fig. 3.

If each of the individual contributions e_i has an approximately triangular frequency distribution there will be a 98% probability that the assembly will lie within the central $\pm\frac{1}{\sqrt{n}}$th of the total possible range. Such a frequency distribution might result from a moderate tolerance applied to a feature which is moderately difficult to control followed by patrol inspection. Such a distribution is shown in fig. 4.

Where a tolerance is applied that is easy to achieve we may expect that there will be a better probability than 98% that the assembly will lie within the central $\pm\frac{1}{\sqrt{n}}$th of the possible range.

If precautions are taken to make the individual contributions e_i as similar as possible, by the judicious allocation of equal allowances for each source of error, and by suitable inspection techniques we see that

$$E = \sqrt{n\,\bar{e}^2}$$

where $\bar{e}$ is the average contribution arising from each source and where n is the number of sources of error.

So, the allowance for each source of error can be

$$\boxed{\bar{e} = \frac{E}{\sqrt{n}}} \qquad \text{(A)}$$

For comparison and standardisation with the normal distribution, the standard deviation or RMS deviation of the normal frequency distribution is given by

[illegible]

and where, again we may equate

$$e_1^2 + e_2^2 + e_3^2 + \ldots\ldots e_n^2 \simeq n\bar{e}^2$$

so that

$$\sigma \simeq \sqrt{\frac{n\,\bar{e}^2}{n}}$$

or $$\sigma \simeq \bar{e} \quad \left(\simeq \frac{E}{\sqrt{n}}\right)$$

That is, we may make the individual allowances approximately equal to the image error magnitude corresponding to the standard deviation of its frequency distribution.

<u>Asymmetric Image Errors</u> (Field tilt, surface irregularity and axial coma)

In this case we are considering errors which may be represented by radial vectors. These vectors need to be evenly distributed and of reasonably uniform length for the statistical arguments to apply.

Fig. 5 shows these radial vectors, as though one was looking along the optical axis.

Alternatively, one can plot the vectors as resolved into the datum azimuth, as shown in Fig. 6. In Fig. 6 you can see that if the errors are evenly distributed in azimuth and of uniform magnitude we have a cosinusoidal distribution of resolved magnitudes with a peak value of $|\bar{e}|$.

$|\bar{e}|$ "the modulus of e bar" looks a bit fussy but serves to distinguish between this quantity and $\bar{e}$ that we had before, and it might keep the mathematicians happy.

Such a cosinusoidal distribution has an RMS value given by

$$\sigma \simeq \frac{|\bar{e}|}{\sqrt{2}} \qquad \text{(Standard Result)}$$

and by comparison with the result for symmetric image errors we see that we can set

$$|\bar{e}| \simeq \frac{E}{\sqrt{n}}\sqrt{2} \qquad (3)$$

4. Application of surface tilt allowances

All this theory [illegible] to communicate the results of tolerance calculations to the craftsman who is making the component or the production engineer who is planning the production processes.

The medium of communication is the drawing set for the optical instrument concerned and fig. 7 shows the essential features of a drawing set for a reflex photocopying objective.

The important aspect of the component drawings shown in fig. 7 are the datums and the geometrical tolerances related to these datums.

Geometrical tolerances are tolerances of shape as opposed to size and they tell the production engineer and the craftsman how to make a component.

There is an error on the top illustration of fig. 7. The basic concentricity datum is shown as F and the bores are all toleranced for concentricity from that datum. In fact it is more important that the bores are all concentric to each other and their concentricity to datum F is not so important.

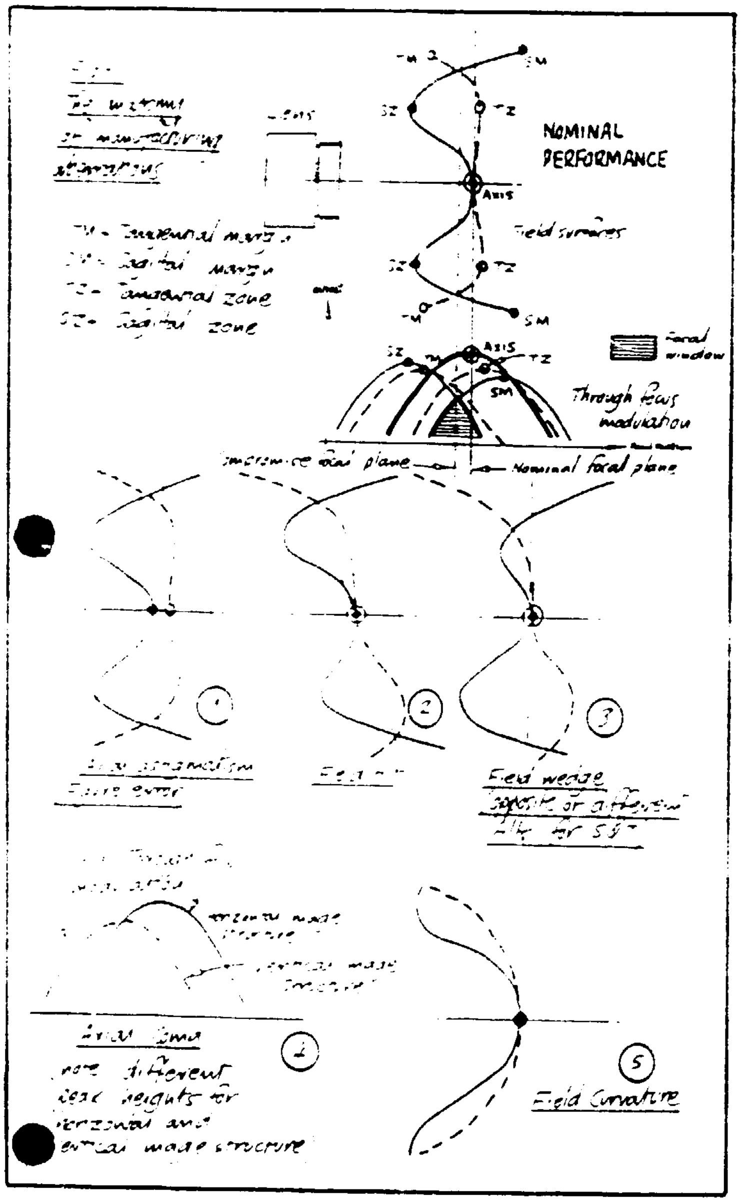
The tolerancing of the doublet is based on a manufacturing technique which concentrates on the optical centration rather than the mechanical edge-alignment of the two components.

5. Summary of tolerance requirements and ranges

The attached table summarises th[illegible]res of optical parts that have to be toleranced and the range of values for those tolerances that are generally applicable.

OPTICAL TOLERANCES

		Minimum	Maximum
1	Glass		
1.1	Refractive index (n)	± .00020	± .001
1.2	Dispersion (ν)	±.2%	± .8%
1.3	Homogeneity	±.0000025	±.000025
	(Refractive index)	$\pm 2.5 \times 10^{-6}$	$\pm 2.5 \times 10^{-5}$
1.4	Striae (Threads)	Precision Quality "Good Edge"	Normal Quality "Good Flat"
1.5	Stain Characteristics	Depends on chosen glass	Depends on chosen glass
1.6	Absorption	1% at 400nm	15% at 400 nm
2	Surfaces		
2.1	Radius	.05%	.2%
2.2	Sphericity or asphericity	[illegible] Fringe	[illegible] Fringes
2.3	Cosmetics	Very Good!	Very Bad!
2.4	Cleanliness	Clean!	Not so clean!
3	Glass Components ("Lenses" & Prisms)		
3.1	Centre thickness	±.01mm	±.2mm
3.2	Centration	.5' arc	5' arc
3.3	Diameter	+0, - .01mm	+0, - .2mm
3.4	Angle	2" (seconds) arc	10' (minutes) arc
4	Metal Components		
4.1	Bore Ø	+ .01mm, -0	+ .2mm, -0
4.2	Parallelism	.005mm	Depends on tooling
4.3	Concentricity	.005mm	Depends on tooling
4.4	Length	± .02mm	± .2mm
5	Complete lenses		
5.1	Focal length or object to image distance	± .1% By Adjustment	± 3%
5.2	Distortion	± .05%	Fish eye
5.3	Image quality	Diffraction limited	!
6.	AR Coatings		



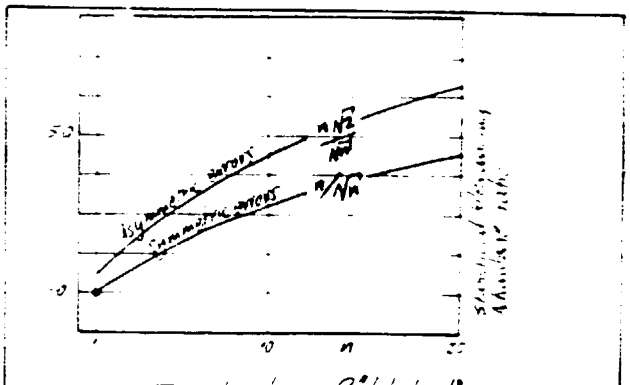


Fig 2 The advantage of "statistical" tolerancing

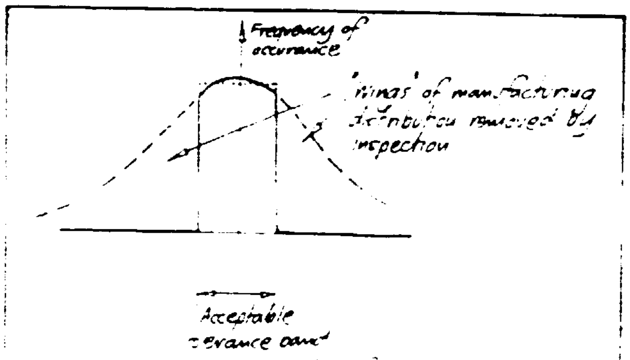


Fig 3 Component rectangular frequency distribution

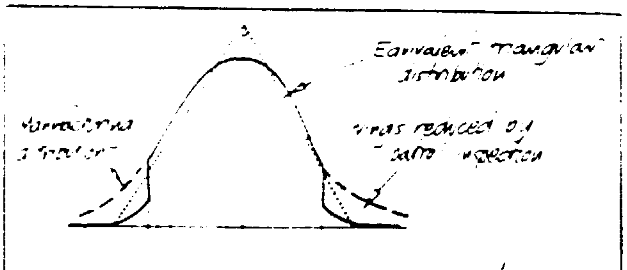


Fig 4 Component triangular frequency distribution

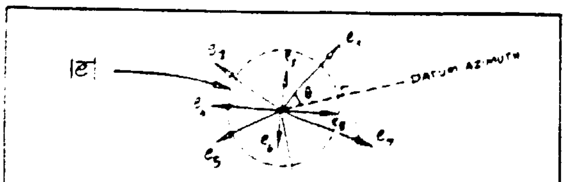


Fig 5 End view of asymmetric image error vectors

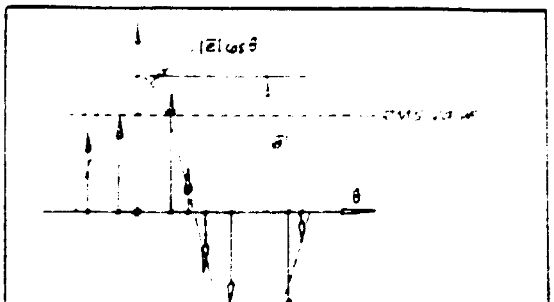


Fig 6 Resolved vectors versus θ

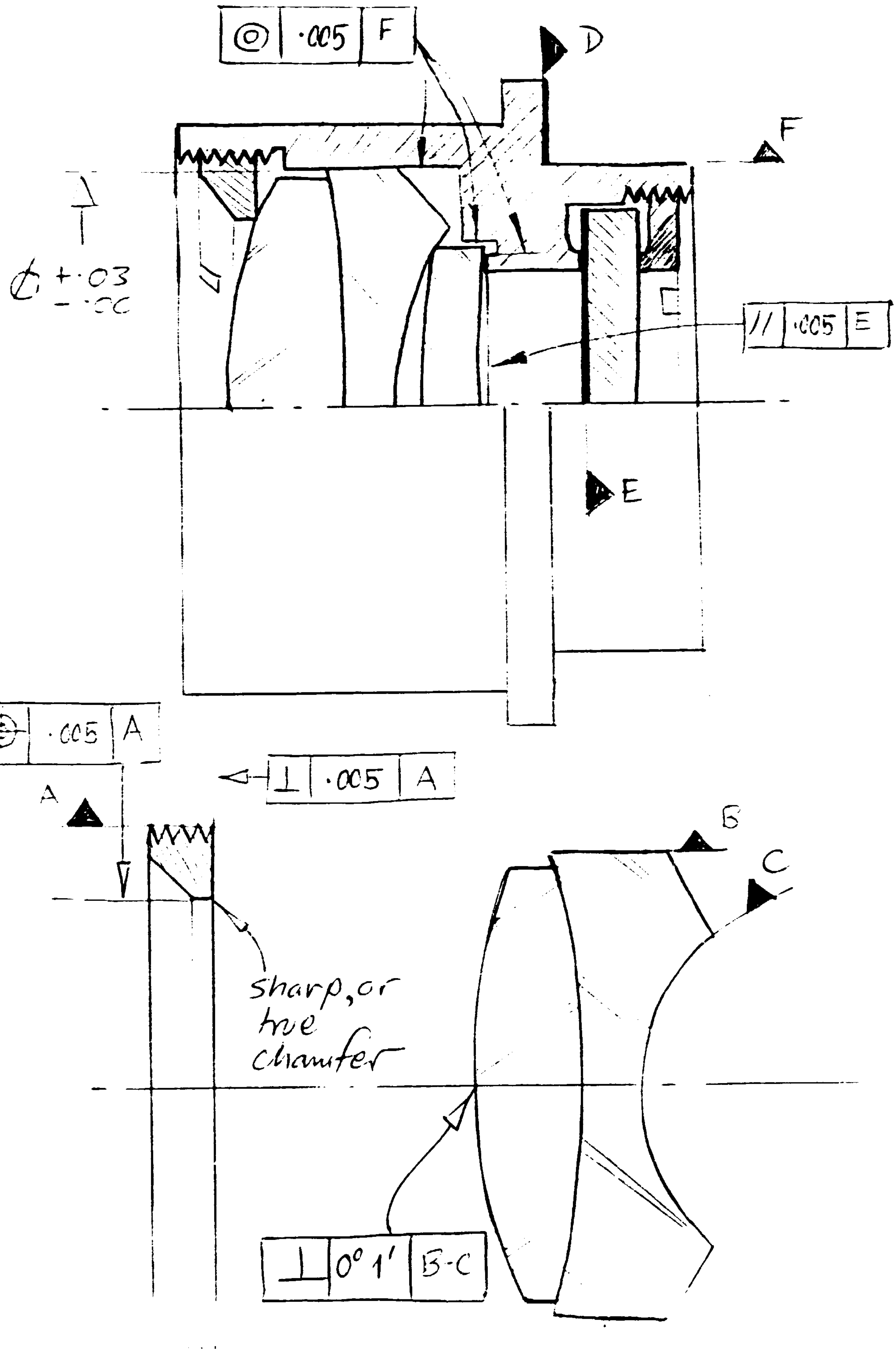


FIG 37 DATUMS AND GEOMETRICAL TOLERANCES

iii) THE DESIGN OF OPTICAL INSTRUMENTS

(including microscopes

The first stage of developing a new optical product is to define the specification of each optical part, whether it be an objective, an eyepiece, some prism assembly or perhaps some opto-mechanical sub system.

The second stage of this process is the detailed design of the optical parts and it is this task which is the subject of this lecture-discussion.

Generally, practical engineers are frightened of the complexity of optical design calculations, but with modern electronic calculators much of the difficulty has been removed and these calculations can be easily mastered: they can be a source of pleasure, pride and last but not least, profit.

Rays, Waves and Aberrations

First we will discuss some familiar background concepts and remind ourselves of a friendly old equation. In the first diagram which is entitled "Rays and Waves" there is shown the fundamental physical nature of image formation, which is based on the precise path of rays from object points to image points, or on the exact shapes of the wavefronts converging on the image points.

Also shown in the first diagram is an interferogram of a deformed wavefront (more interferograms are shown in the second diagram).

The equation shown at the bottom of the first diagram:

$$\frac{1}{l'} = \frac{1}{l} + \frac{1}{f}$$

may be directly derived by consideration of the associated diagrams: when parallel light falls on a convex lens that lens impresses a curvature of 1/f on the incident wavefronts, so that they converge on the focal point. When a wavefront converges on a positive lens, as shown in the other diagram, so that it has a curvature of 1/l at the lens, the lens again impresses a curvature of 1/f on it and the curvature of the wavefront become 1/l', thus but this derivation is clear, simple and adequate and it has the additional advantage that we can clearly see the physical principles involved. Many optical calculation equations are just as simple in their concept as this one. For example, consider the equation for focal length shown in the third diagram. This equation may look more ferocious than the previous equation but it is an exact formula for focal length which applies to any single lens component, however thick it may be.

Focal Length in Engineering Optics

In the equation for focal length shown in the diagram entitled "Calculations" the radius of curvature is taken to be positive if the centre of curvature is to the right of the surface, just as the object and image positions in the previous diagram are taken as positive because they are to the right of the lens.

The equation for focal length given here is exact, it does not make any assumptions about the thickness of the lens component and it calculates effective focal length. The equations for AP and A'P' then become vital if the position of the principal points are to be calculated and the focal points are to be located with respect to the lens surfaces.

Thus, if an image is to be located in a particular plane with a particular magnification we can calculate f and A'P' (if M ≠ 0) or we can calculate A'F' (if M = 0).

So if it is required to replace a lens component we can arrange for the image to be in exactly the same place as before if we take due account of f and A'P' and also calculate the sag of the surface sitting against the mechanical shoulder.

Note that the formula for surface sag given on the diagram entitled "Calculations" uses the modulus of the value of surface radius, that is, the positive value.

This may all seem rather elementary but there are many situations where the image formed by a single lens must be in a precisely defined image plane, or where a lens must be replaced without disturbing the focal properties of the optical system.

Achromatism

[illegible]

The optical engineer is frequently required to design achromatic doublets which correct this particular error.

The correction of chromatic aberration is accomplished by combining positive and negative lens components in contact, where the dispersion of the optical material of the two (or more) components are different.

If for example we want an achromatic doublet with a positive focal length we must combine a more powerful positive lens with a less powerful negative lens. If the chromatic aberrations of these two components are to be equal and opposite it is obvious that the less powerful negative lens must be made of a more dispersive optical glass than that which is used to make the positive lens.

If the dispersions of the two glasses are chosen in this way but the refractive indices are chosen to be equal the lens will have monochromatic properties which are just like a simple positive lens, that is, positive (undercorrected) spherical aberration. If however the refractive indices of the two components are chosen to be <u>different</u>, the contact surface can also be used to correct the spherical aberration. In the case of a positive doublet the spherical aberration will be naturally positive and a curved contact surface with a higher refractive index on the side that makes the contact surface refractively negative will reduce the overall spherical aberration.

In this way we choose to make our negative component out of high refractive index, high dispersion glass ("Flint" glass) and our positive component out of low refractive index, low dispersion glass ("crown" glass).

Now, what precisely should the focal lengths of the two components be?

Well, recalling that a lens of focal length f imposes a curvature 1/f on a plane wavefront we know that

$$\frac{1}{f} = \frac{1}{f_A} + \frac{1}{f_B}$$

where $1/f$ is the overall wavefront curvature increment and $1/f_A$ and $1/f_B$ are the effects produced by the two constituent components.

So, for zero overall chromatic aberration

$$\frac{1}{f_A V_A} + \frac{1}{f_B V_B} = 0$$

Putting these two equations together we get

$$f_A = - \frac{V_A - V_B}{V_A} \qquad f_B = F \frac{V_B - V_A}{V_B}$$

A further important practical trick is to cement these two components together and to do this we choose one of the three curves and then compute the other two curves using the relation

$$\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

for each component.

If the achromatic doublet is to be used with the object at infinity it is usual to to choose the plano-convex form of the double lens combination, in which case $(R_2)_B$ of the [illegible] lens [illegible] infinity and

$$(R_1)_B = \frac{1}{\frac{1}{f_B(n_B - 1)} - \frac{1}{\infty}} \qquad \text{while } (R_2)_A = (R_1)_B \text{ cemented lens}$$

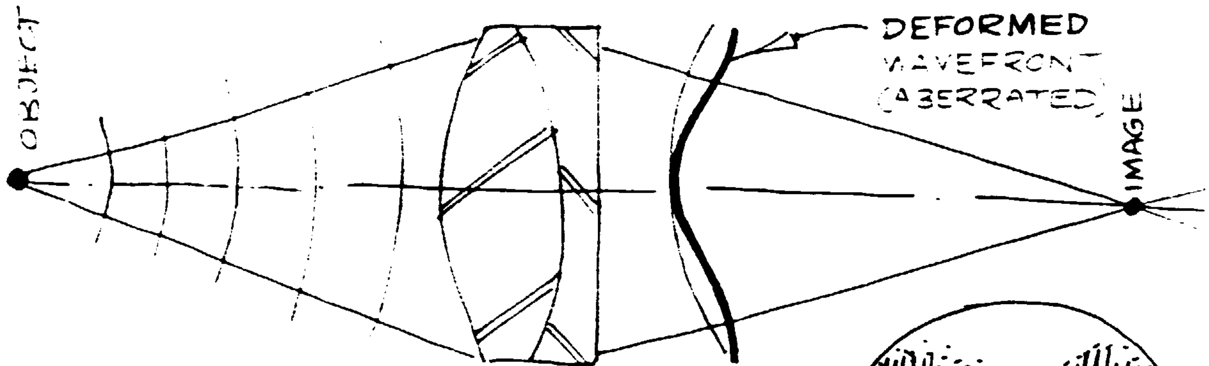
and $$(R_1)_A = \frac{1}{f_A(n_A - 1) + \frac{1}{(R_2)_A}}$$

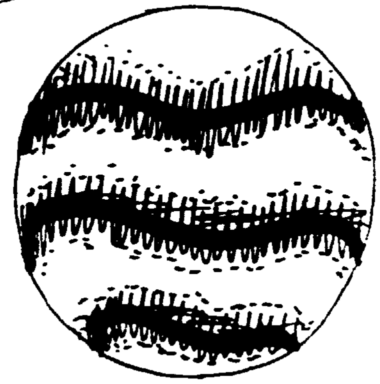
In the case of a doublet which is to have a negative overall focal length the negative component will be made of low dispersion glass and the positive component will be made out of high dispersion glass.

Representative lens designs

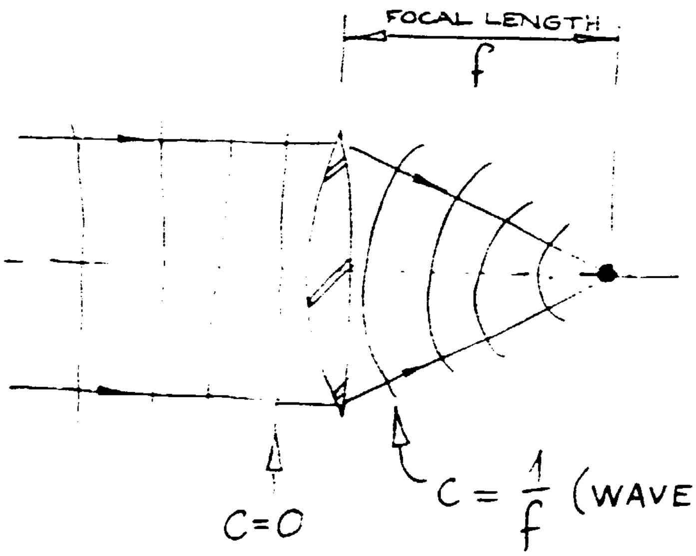
The final illustration of this appendix shows the way in which different numbers of optical components may be combined to produce useful optical devices.

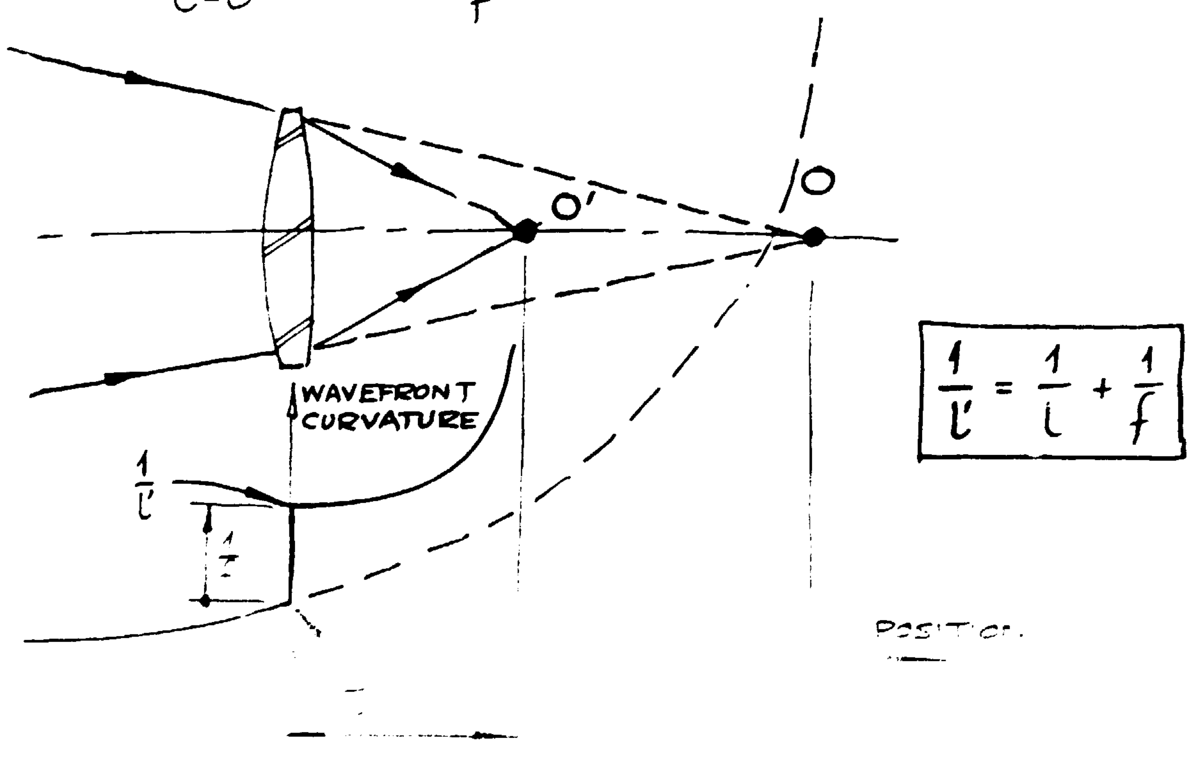
RAYS AND WAVES



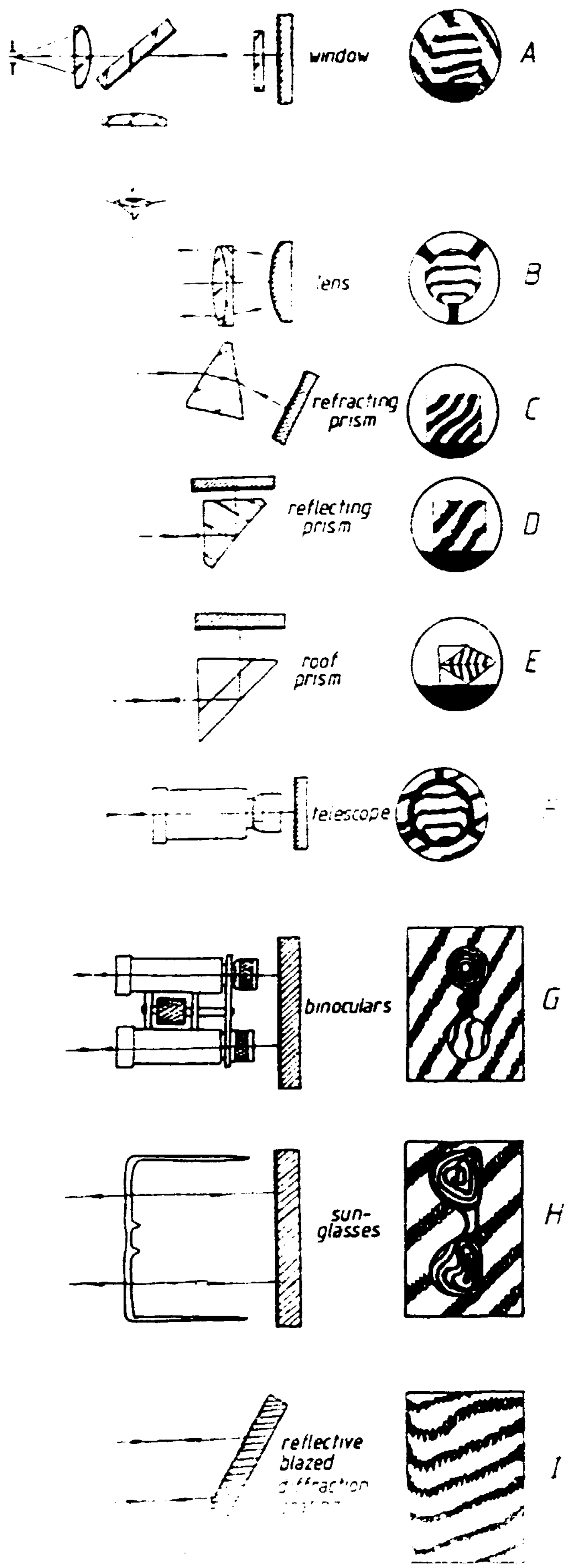


INTERFEROGRAM
SHOWING WAVEFRONT
SHAPE

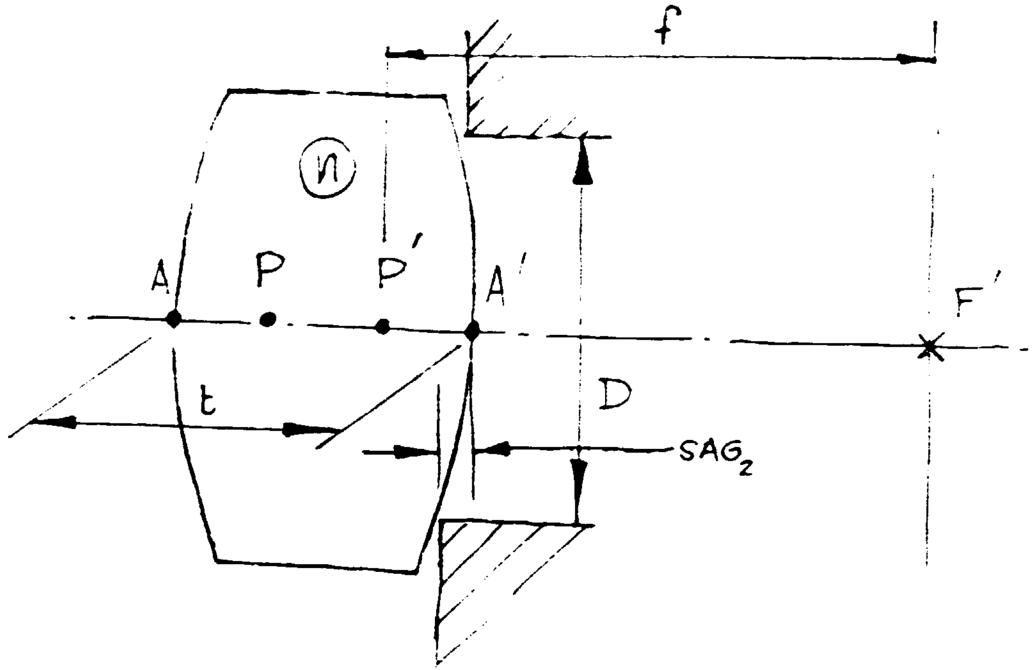




INTERFEROGRAMS



CALCULATIONS



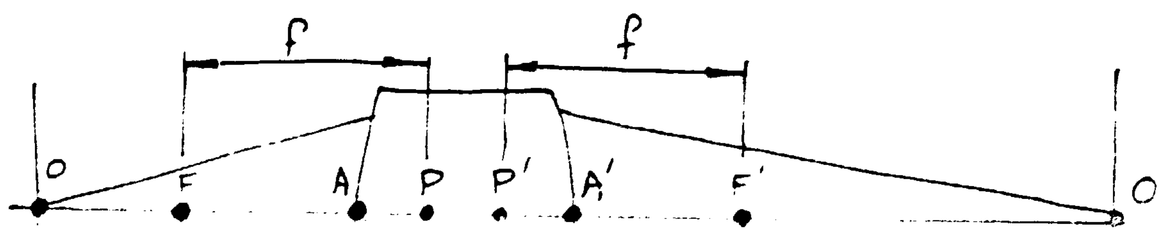
$$f = \frac{1}{(n-1)\left(\frac{1}{R_1} - \frac{1}{R_2} + \frac{t\,(n-1)}{R_1 R_2 n}\right)}$$

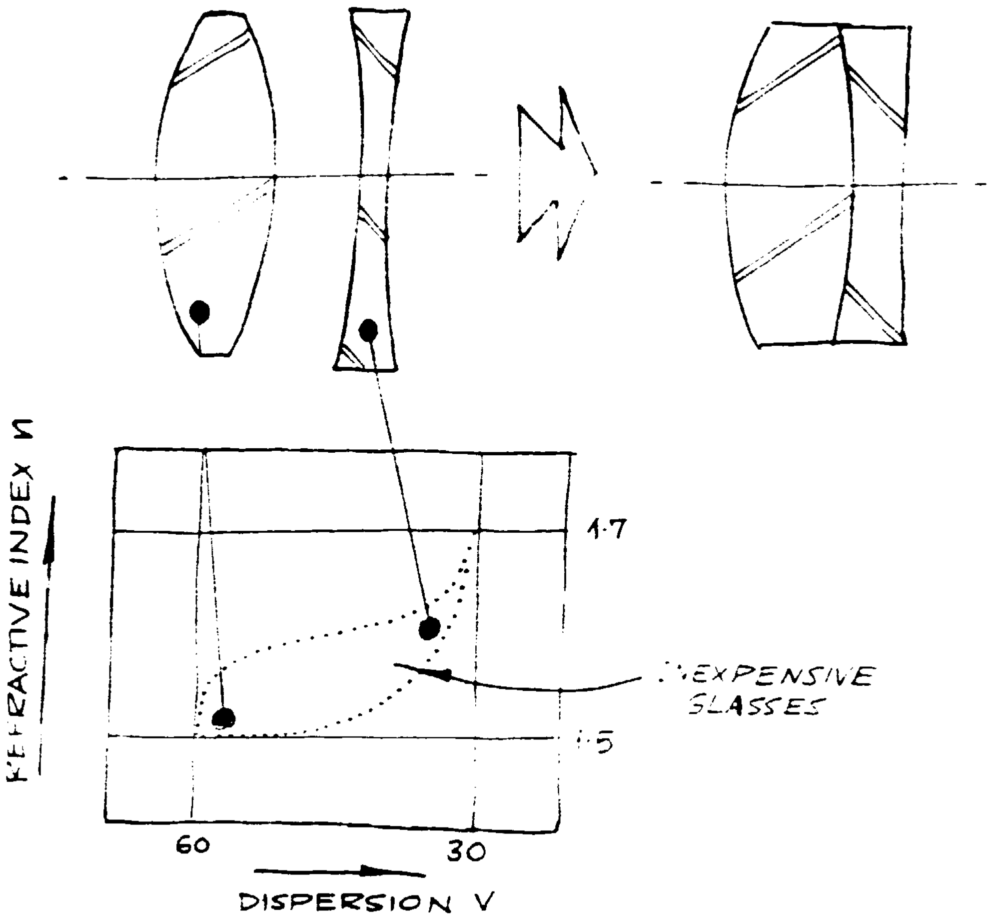
$$AP = \frac{t\,(1-n)}{R_2\, n} f$$

$$A'P' = \frac{t\,(1-n)}{R_1\, n} f$$

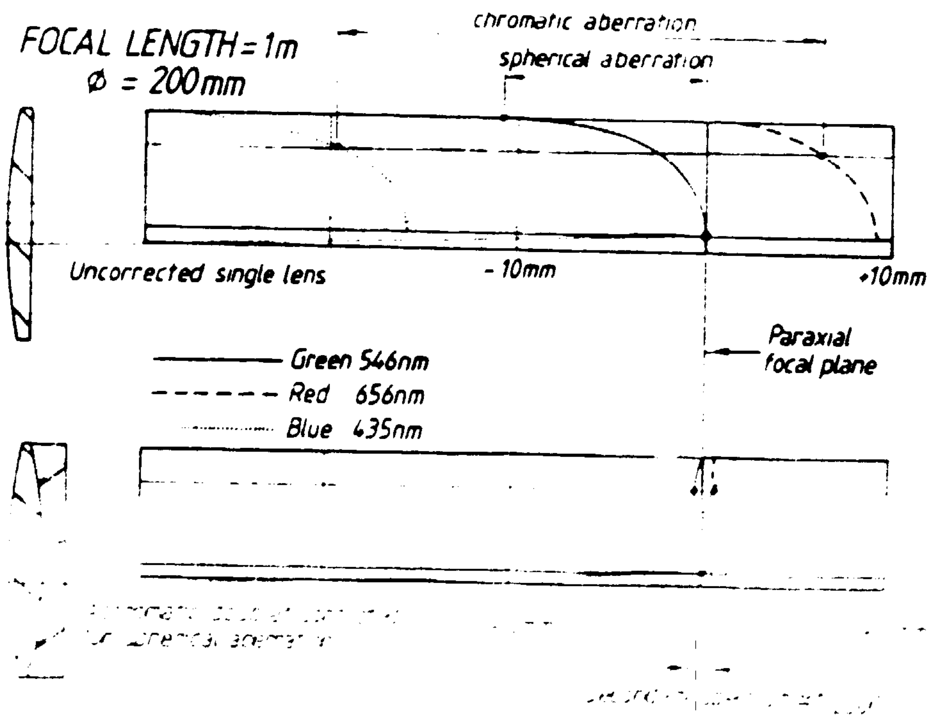
$$A'F' = A'P' + f$$

$$sag = R_2 - \sqrt{R_2^2 - \left(\frac{D}{2}\right)^2}$$

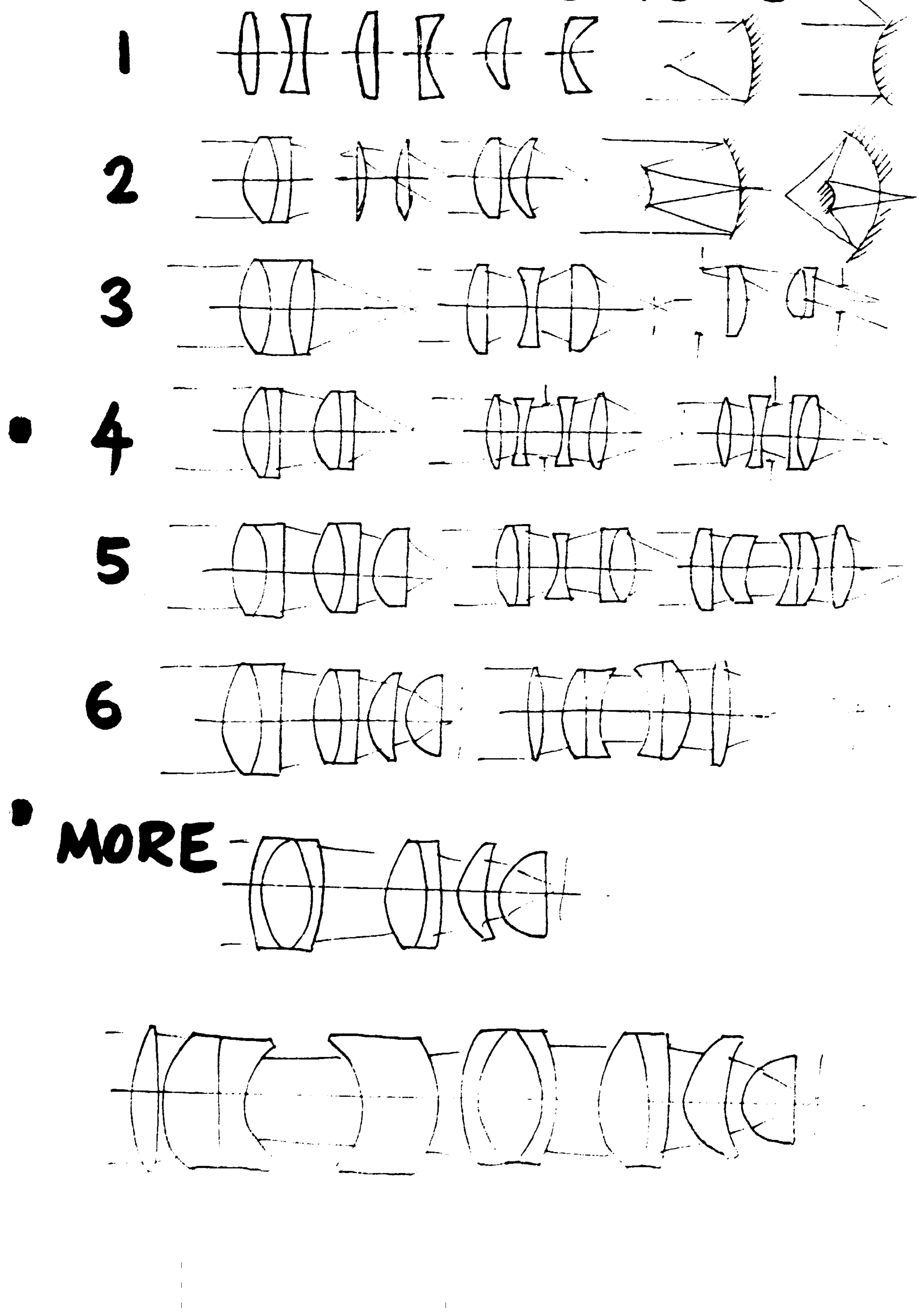




ACHROMATIC DOUBLETS



LENS DESIGNS



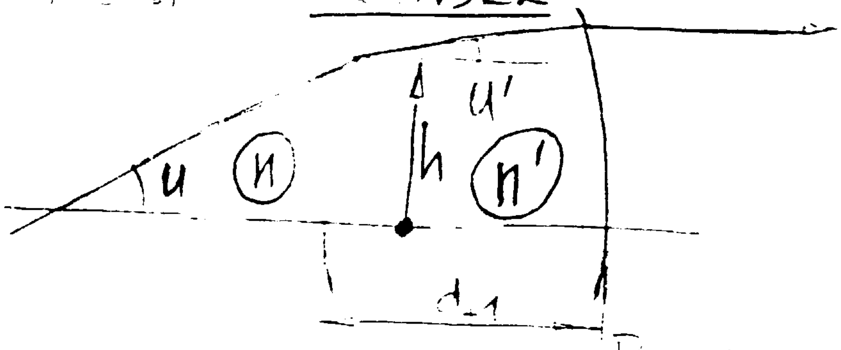
APPENDIX 2

STANDARD RAY TRACE FORMULAE

1) Paraxial

$$u' = \frac{nu - hc(n'-n)}{n'} \quad \text{REFRACTION}$$

$$h_{+1} = h + du' \quad \text{TRANSFER}$$



2) Finite Meridian

REFRACTION

$$I = \sin^{-1}(\rho c + \sin U)$$

$$\phi = I - U$$

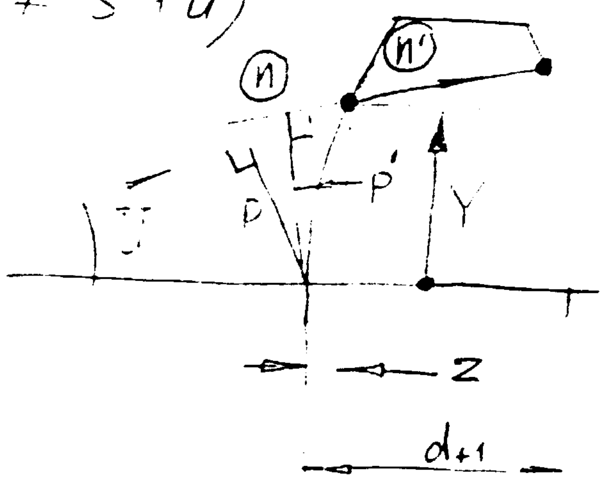
$$Y = \frac{\rho(1+\cos\phi)}{\cos U + \cos I}$$

$$Z = \frac{\rho \sin\phi}{\cos U + \cos I}$$

$$I' = \sin^{-1}\left(\frac{n}{n'} \sin I\right)$$

$$U' = I' - \phi$$

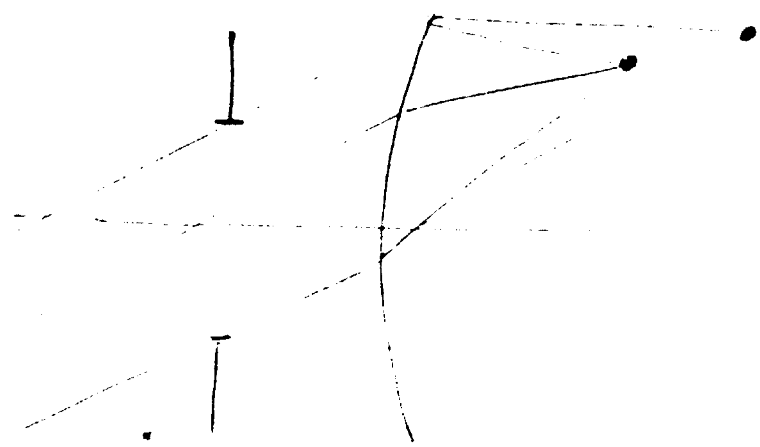
$$\rho' = \rho \, \frac{\cos U' + \cos I'}{\cos U + \cos I}$$



Then, for OPDs and S+T tracing

$$D = \frac{z - z_{-1} + d}{\cos U}$$ & OPTICAL PATH $= D \times n$

3) S & T Raytrace



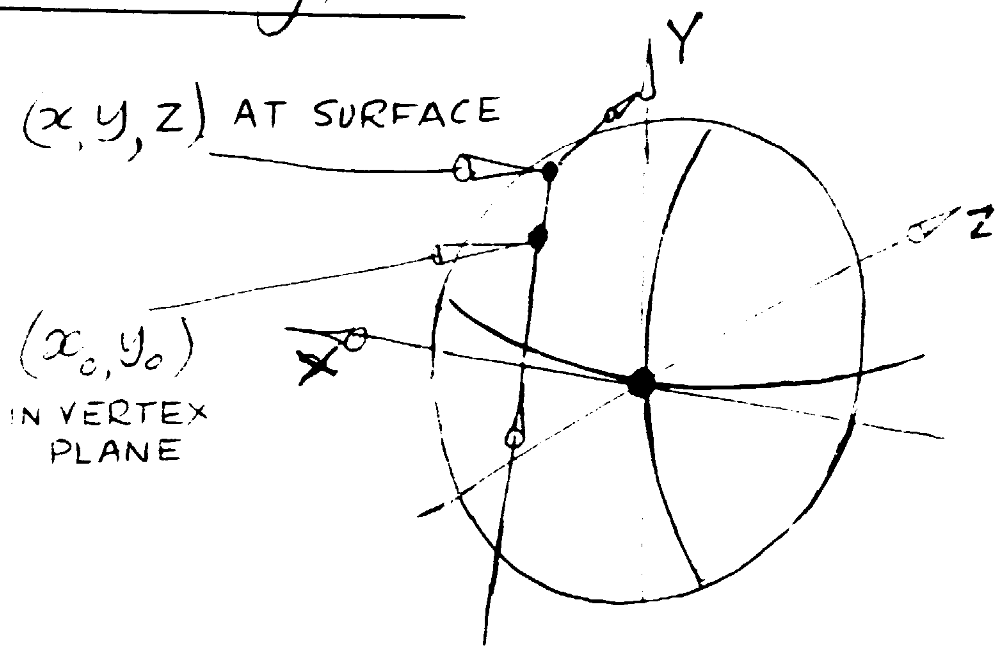
$$S' = \frac{n'}{c(n'\cos I' - n\cos I) + \frac{n}{S}}$$

$$T' = \frac{n'\cos^2 I'}{c(n'\cos I' - n\cos I) + \frac{n\cos^2 I}{T}}$$

Refraction

$$S_{+1} = S' - \bar{D}$$ Transfer

4) Skew Raytrace



TRANSFER

$$x_0 = x_{-1} + \frac{L}{N}(d - z_{-1})$$

$$y_0 = y_{-1} + \frac{M}{N}(d - z_{-1})$$

$$\cos I = \sqrt{(N - c(Lx_0 + My_0))^2 - c^2(x_0^2 + y_0^2)}$$

$$\Delta = c(x_0^2 + y_0^2) / (\cos I + N - c(Lx_0 + My_0))$$

$$x = x_0 + L\Delta$$

$$y = y_0 + M\Delta$$

$$z = N\Delta$$

$$D = (d - z_{-1} + z)/N$$

...CT

$$n' \cos I' = \sqrt{n'^2 - n^2(1 - \cos^2 I)}$$

$$K = c(n' \cos I' - n \cos I)$$

APPENDIX 3

[illegible]

[illegible]

[illegible] BY

Dr. Jagpal Singh)
Mr. Rajesh Rampal) Project Personnel
Mr. N.K. Jain)
Mr. Bhup Chand)

Dr. S.K. Sachdev)
Mr. J. Maxwell) Advisers

Circulation: Dr. R.S. Balain & Mr. K. Popov

1. General:

To make windows to 10 seconds parallelism and 8th wavelength flatness at a diameter of up to 500mm is a major project, ranking with some of the major achievement in Optical Fabrication world wide. This should be seen as a challenge by IRDC Engineers and management, and while it will be difficult to achieve even 5x these tolerances on surface form and perhaps 2x on parallelism, the prestige that will come from the achievement and the morale boost to the management team and engineers involved will be of great benefit to IRDC.

2. Management:

2.1 The sucess of a project of this magnitude is dependent on good management at all levels. Efforts should be made to make all personnel involved feel part of an elite team. The engineers and technicians will in particular feel exposed and threatened by the magnitude of the technical problems and they should be supported at every stage by their management officers.

2.2 The management resources available for this project appear to be limited. Dr. Jagpal Singh is already fully loaded with many technical and managerial activities associated with the growth of IRDC. Mr. Rajesh Rampal is fully employed developing the vacuum coating facility. Mr. N.K. Jain is due to go for 3 months training overseas.

2.3 A detailed project timescale plan should be prepared which identifies all activities so that all team members know their [illegible].

2.5 It may be necessary to [illegible] technical consultants to help with specific manufacturing problems. In particular, the following establishments and contact personnel can provide suitable technical assistance:-

A) Mr. [illegible]
Ordnance Factory,
Dehradun, [illegible]

B) Mr. A.K. Ghosal,
National Instrum[illegible]
Calcutta, Bengal.

C) Mr. [illegible] Rao,
[illegible]co Unit of [illegible],
Machilipatnam, A.P.

3. Workshop Requirements

3.1 The present workshop conditions are temporary, according to plans with Dr. Jagpal Singh, and as such they are not suitable for [illegible] working of such large windows. In particular it is at the polishing and figuring stage that [illegible] conditions must be provided both in terms of temperature stability and cleanliness.

3.2 Temperature control should be provided which aims at the most easily achieved stable temperatures. With winter coming on, heating in the nights may be necessary.

3.3 At this time, facilities for cleaning are very poor. In the modern industrial sector cleanliness and tidyness are important for morale and efficiency but in large diameter optical work cleanliness and tidyness are necessary before the work can be done at all.

4. Quality Assurance and Technical Specification

4.1 With a project of this type there must be a close liason between the customer and the contractor, this requires progress meetings to be arranged so that misunderstandings may **not** arise and so that the customer is reassured that his interests are being looked after.

4.2 There is an immediate need to interrogate the customer about the details of the technical specification of these windows. In particular we require the following information so that our project engineers can prepare a technical appreciation of the requirements:

i) Linear aperture of the optical instruments that are looking through the windows.

iii, The type of detectors that are being used by the optical instruments.

iv. The ideal area of the window.

v. The area of the window which is not masked by the mounting.

vi, The wavelength of the light that the optical instruments need.

4.3 The glass material that has been supplied by the customer has not been accompanied by any technical certificate from the glass manufacturer.

We should receive copies of any technical certificates that are held by the customer. In particular we need to know what the purchasing specification was and whether we have super fine annealed glass or not and also what its homogeneity is.

4.4 The glass pieces supplied have a number of minor blemishes which are being drawn. The completed drawings should be submitted to the customer alongwith a questionnaire about the technical specification as paragraph 4.2 above.

5. Manufacturing Engineering

5.1 It is in this area of manufacturing engineering that the problems will come. Mistakes will be made, new techniques will have to be developed, delays and frustrations will show themselves. The project team and ILDC management must be resourceful, energetic, patient, cooperative, flexible and courageous.

5.2 Aluminium and cast iron tool blanks have been delievered to ILDC and work is in hand to machine them.

5.3 The most important resource that is with ILDC is the LOH PA 500 machine. This machine is probably only just capable of doing this work, being intended for blocks of much smaller components. Modifications may be necessary to reduce its working speed and to in other ways optimise its performance.

5.4 Spherometry is an important working technique in this type of project and a dial gauge bridge device is required to monitor surface form.

5.6 Most of the polishing work will probably be done with the polisher on top of the workpiece to avoid the possibility of major damage resulting from moving the glass piece itself.

5.7 The polisher holder and the grinding tools must not be too heavy so that the work piece is not deformed but they should also be stiff enough so that they will not bend. These conflicting requirements may be adequately met by use of ribbed aluminium tools.

5.8 The polishing slurry may have to be thermostatically controlled. The precise temperatures of the room and this slurry will have to be adjusted by trial and error until a well balanced working temperature has been determined.

5.9 Testing of parallelism may be checked by autocollimation or by oblique laser shearing interferometer.

5.10 During polishing it will be necessary to press the polisher flat before starting work and at regular intervals during the work. To do this it is necessary to use a granite surface plate which is absolutely flat.

6. <u>Training</u>:

6.1 Work may proceed as soon as possible with working some 150mm diameter flats so that some experience may be gained on the Loh H 500 machine.

6.2 Project personnel will benefit from visiting establishments where large optics have been made. In particular, the following establishments have worked on large scale optical components:-

Nainital Observatory
NIL Calcutta

7. <u>Technical Reporting</u>:

Careful experimental and theoretical records should be kept so that the work may proceed systematically and so that if at a future date anybody requires to do this work they may consult the written records.

8. **Summary of Specifications**

8.1 **Delivery:** Glass arrived August 85,
Finished Pieces: End Oct' 85

8.2 **Specifications**

A) Qty 3

Diameter 375mm

Thickness 50mm (Under negotiation) Glass ≥ 55mm

Flatness $\lambda/8$ @ λ = 632nm (both sides)

Cosmetic quality 60/40

Graticules are 10/15 } For comparison
Objectives 60/40 }

Material BK 7

Parallelism 10" seconds

B) Qty 2

Diameter 450mm

Thickness 60mm (Under negotiation) Glass ≥ 57mm

Otherwise as 2.1 above.

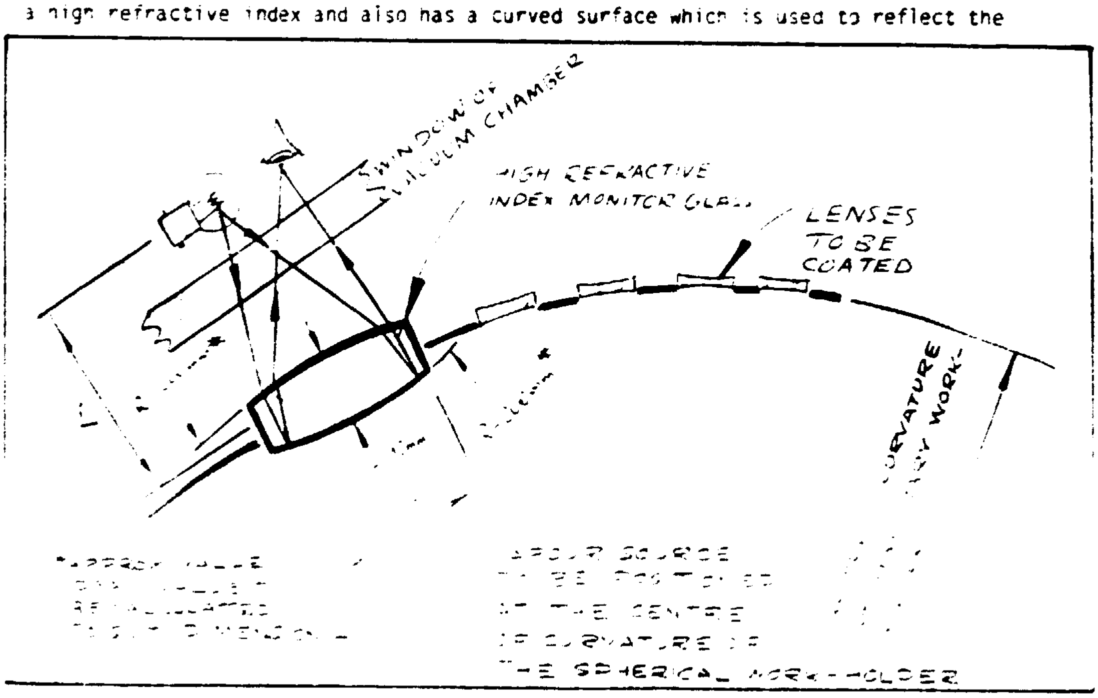
THE VISUAL MONITORING OF THE THICKNESS OF MAGNESIUM FLUORIDE ANTIREFLECTION COATINGS FOR OPTICAL SURFACES

The use of a quarter of a wavelength of Magnesium Fluoride as an optical anti-reflection coating is well known (see for example L. Holland, The Vacuum Deposition of Thin Films, Chapman and Hall 1956, p.276).

The efficiency of Magnesium Fluoride as an antireflective coating is dependent on the refractive index of the substrate glass: the higher the glass refractive index, the lower the reflectivity at the design wavelength. When the refractive index of the glass is the square of the refractive index of Magnesium Fluoride (1.38) there is a zero of reflection at the design wavelength, but a residual reflectivity at other wavelengths, so leading to the characteristic "bloom" colours associates with such coatings. The zero reflectance conditon is not achieved with any practical optical glasses but at refractive indices approaching 1.7 for the substrate glass reflectivities much less than 1% are achieved and the "bloom" colour is very evident.

The bloom colour associated with an antireflective layer of Magnesium Fluoride is amber when the reflectivity is minimum in the blue region of the spectrum, magenta for the green region and blue for the red region. These colours are very clear and easy to monitor on high index glasses. This leads to an exceptionally simple and effective visual monitoring process which is widely used in one form or another throughout the optical industry worldwide. This process is of economic importance because it is so inexpensive and reliable.

The monitoring technique is extremely efficient when the monitor glass has a high refractive index and also has a curved surface which is used to reflect the



light from a hand held monitor lamp back to the pupil of the operator's eye. This leads to a standard design of monitor glass which has two identical convex surfaces of such a radius that the reflective viewing condition is met whichever way the monitor glass is used. The scheme is shown in the attached diagram. The monitor glass may be repolished and re-used twice - once on each side.

The operator is presented with a view of the lower surface of the monitor glass flooded with light from the lamp he holds and as the evaporation proceeds the colour of this reflection proceeds through amber to magenta and on to blue. The operator can switch off the evaporation heater at the chosen colour point.

There are other practical requirements to be met if the antireflective films are to be successful:-

1) The operator must be able to switch off the heating current from the observation position and also control the heating to achieve a spatter-free evaporation.

2) The Magnesium Fluoride powder must be absolutely dry and the powder well separated to avoid spattering.

3) The lenses must be absolutely clean.

4) The vacuum system must be pumped with silicon oils.

5) The vacuum system must be absolutely clean.

6) The lenses must be discharge cleaned.

7) The ultimate vacuum should be better than 10^{-5} Torr.

8) The vapour source must be at the centre of curvature of the work holder.

9) The lenses should be baked to 250°C or 300°C prior to evaporation.

INDUSTRIAL PROJECTS

LABORATORY EQUIPMENT TRADERS

Mr N.K. Jain and Mr K.K. Verma

Project Testing of oil immersion objectives without the use of immersion oil.

Report A Twyman-Green interferometer was built which had a reference objective in one arm and the test objective in the other arm. The reference and test beams were reflected internally off the external flat surface of the front hemispherical lens in each case.

Shortage of time forbade the completion of this project but I am confident that this instrument can be made to work.

ELECTRONIC INSTRUMENTATION/EYEOPTIKA

(Mr P.K. Jain and Mr K.K. Jain)

Project Design and checking of microscope objective designs.

Report One x10 microscope objective design was checked and found to be well corrected.

Another x40 design was checked and was found to be very poor. This objective was redesigned for this company.

3) ELECTRO OPTICS

(Mr A. Bhatia and Mr V. Sareen)

Project Zoom projection lens design

Report Approximately one day was spent discussing this company's project. The basis for a design was developed and the calculations handed over to the engineers from this company.

4) RAY ENTERPRISES

(Mr D. Chowdhry)

Project This company would like to develop an introscope of length 650mm and dia 6mm with a +/- 15 degree field with a magnification of 4 or more at the eyepiece.

Report The project was discussed but no work was done on it.

5) CROWN OPTICAL WORKS

(Mr J.N. Bhola)

Project This company has built a zoom stereo microscope but it had many quality and design problems, namely Resolution, Field Curvature and Zoom focus holding which are optical design problems and collimation errors and generally low mechanical integrity.

Report The project was discussed but no work was done on it.

6) INDIA OPTICS AND SCIENTIFIC WORKS

(Mr Aggarwal and Mr Chopra)

Project This company would like to develop a zoom stereo microscope.

Report Project discussed but not worked on.

7) JAIN SCIENTIFIC EQUIPMENT

(Mr P.K. Jain)

Project Interference microscope

Report This product has been developed by CSIO. This company together with [illegible] should approach CSIO to review the possibility of taking their help.

8) SETHSONS

(Mr K. Seth)

Project Episcopic Projector and Sighting Telescope.

Report Lens designs suitable for both these instruments were passed to Mr Seth.

APPENDIX 5

EQUIPMENT

There are two equipment lists.

The first is a list of basic requirements, mostly of a modest level of investment. The second list is of mostly major capital items.

The equipment on the first list is vital in the short term for the efficient running of the IDDC optical section. The equipment on the second list is necessary if IDDC is to expand to meet the challenges of the developing optical industry in Ambala.

EQUIPMENT LIST I

			Estimated Approx $
1	MECHANICAL METROLOGICAL EQUIPMENT		
1.1	Set of slip guages		2,000
1.2	2m x 1.5m surface table		3,000
1.3	Set of internal bore micrometers (3 arm type)		2,000
1.4	Set of rod micrometers, 25mm -3m		2,000
1.5	Lighthouse type height standard for metrology on surface table		1,500
1.6	Qty 5 lens centre thickness guages (dial guage and micrometer type)		1,500
1.7	Angle slip guages		1,500
2	OPTICAL TEST EQUIPMENT		
2.1	[illegible] Twyman Green interferometer, small size		6,000
2.2	Custom built optical test bench for infinity conjugate lenses with nodal slide and precision bearing facilities. May be made in house		5,000
2.3	As I 2.2 but for finite conjugate lenses		6,000
2.4	Hilger Chance type refractometer		3,000
2.5	Hilger type focal collimator		5,000
3.	Optical Computing (Design) Laboratory		
3.1	Quantity two Microcomputers with optical design software (Hewlett Packard make or Vax make)	10,000	
3.2	Recurrent expenditures for stationery, magnetic tapes etc.	2,000 per annum	
4.	Mechanical Workshops		
4.1	Precision chasing lathe Hardinge make	10,000	
4.2	Metrological equipment for linear and angular calibration. Several major items, each less than $1,000.	10,000	

EQUIPMENT LIST II

			Estimated Approximate Price
			$
II	1.	<u>Vacuum Coating</u>	
II	1.1	Spectrophotometer, Double Beam	
		a) Visible UV-NIR .25 - 2.5µ	25,000
		b) Infra Red 2.5 - 25µ	25,000
II	1.2	Additional Indian-make 0.5m diameter vacuum plant and ancillary equipment for training local industry	40,000
II	1.3	Coating hardness testers, manual type	50
II	1.4	Silicon oil for indigenous coating plants in addition to silicon oil which will be available with Balzers equipment	3,000 per annum
II	1.4	Other consumables (Molybdenem boats, chemicals etc.)	10,000 per annum
II	1.5	Interference microscope for thickness measurements	3,[illegible]
II	2.	<u>Optical Glass working</u>	
II	2.1	Centering and edging machine, for diameters up to 150 or 200mm	25,000
II	2.2	Laser centering device	7,000
II	2.3	Lapping and polishing machine: continuous type with polisher dressing up to 250mm diameter at each of three stations and capability for crystal polishing (Logitech type)	20,000
II	2.4	Crystal cutting machine	7,000
II	2.5	Granite surface plate with continuous surface diameter (or square side) 600mm. May be Indian manufacture	1,000
II	2.6	Standard accessories for existing machines including spare parts	10,000
II	3.	<u>Optical Testing and Experimental Laboratory</u>	
II	3.1	Definition collimator for telescope testing. Aperture 100mm, Focal length 1m.	[illegible]

II	3.3	Scatter plate interferometer Ealing Beck type	1,000
II	3.4	Polaroid camera with anastigmatic lens and close-up attachment for 4"x5" film size	500
II	3.5	Single lens reflex 35mm camera with manual and automatic exposure facilities	200
II	3.6	Black and white closed circuit T.V. system including camera and monitor	1,000
II	3.7	Laser alignment equipment including 1mW laser (He Ne), Beam expander and beam stearing modules	2,500
II	3.8	1 Watt Argon-Ion laser for Holography	16,000
II	3.9	High intensity monochromator	4,000
II	3.10	Optical Transfer function measuring equipment [illegible] or [illegible] type	[illegible]
II	3.11	Ellipsometer, Gaertner type	10,000
II	3.12	Research microscope with metallographic, fluoroscopic, polarising, phase contrast, interference, dark ground and high power flat field apochromatic oil immersion systems	[illegible]
II	3.13	Goniometer for universal angular measurements	40,000
II	4.	<u>Optical Computing (Design) Laboratory</u>	
II	4.1	Quantity two Microcomputers with optical design software (Hewlett Packard make or Vax make)	10,000
II	4.2	Recurrent expenditures for stationery, magnetic tapes etc.	2,000 per annum
II	5.	<u>Mechanical Workshops</u>	
II	5.1	Precision chasing lathe Hardinge make	10,000
II	5.2	Metrological equipment for linear and angular calibration. Several major items, each less than $1,000.	10,000

UNDP TRAINING FELLOWSHIPS

Host training establishments located in the UK who have made firm formal offers of training for IDDC/UNIDO candidates

The following companies or establishments have all responded affirmatively to a request for them to receive UNIDO trainees, starting in the fourth quarter of 1985:

i)	Cranfield Product Engineering Centre Bedford MK43 OAL	(Independent government funded product development organisation with avionic specialisation)
ii)	J.H. Dallmeyer High Road Willesden, London NW10 2DN	(Major Lens-system Manufacturer)
iii)	National Physical Laboratory (NPL) Teddington Middlesex	(Major National Laboratory)
iv)	O.C.L.I. Donibristle Industrial Estate Dunfermline, Scotland	(Major Optical Thin film supplier)
v)	ERA Institute South Hill Chislehurst, Kent BR7 5EH	(Major independent Opto-electronic research institute)
vi)	Specac Lagoon Road St Mary Cray Orpington, Kent BR5 3QX	(Manufacturer of Optical Components)
vii)	Vickers Instruments Haxby Road York YO3 7SD	(Major Optical Instrument Manufacturer specialising in microscopes)

Each of these hosts has been selected as being capable of providing the very highest standards of training and as each being well matched to the requirements of individual candidates (see below).

IDDC Candidates proposed for training and IDDC requested training programmes

IDDC has approached me directly with the biodata for each of the following [illegible]

Present (Nov 1985) status of training programme organisation

The British Council has, at the behest of UNIDO Vienna, [illegible] Singh and K.K. Krishnatray with [illegible] for 6 months, so endangering [illegible] training offers from Vickers and Dallmeyer.

A.K. Sharma and R.P. Verma are proposed for training in electronics and as only the SIRA and Cranfield contact departments are suitable for such training and as, additionally, SIRA can only take one candidate I have completed arrangements with these two organisations as far as I am able. On this basis A.K. Sharma can be with Cranfield for 6 months and R.P. Verma can be with SIRA for 6 months, their biodata is currently being reviewed by the appropriate officers at each establishment and I anticipate an affirmative response within a few days.

Wastage of Candidates and Training Opportunities

The candidates listed above are the last four of a total of nine that have been proposed to me by IDDC. The balance of five candidates who are no longer listed have either been placed in training elsewhere or have resigned from IDDC. This means that there is a danger that we shall consciously not make use of the N.P.L. or [illegible] as training opportunities, in addition to losing Vickers and Dallmeyer through lack of co-ordination.

CONCLUSION

In spite of careful liaison with UNIDO Officers in Vienna and Ambala, a situation has arisen where a great deal of preparatory work in this programme has been wasted, and there is an immediate danger of ill will being generated with the host training establishments. In view of the wishes of IDDC, the wishes of the trainees themselves and the wasteful and negative situation that has arisen due to lack of co-ordination, I believe that it is vital that UNIDO make every effort to rectify this specific situation in the short term and institute procedures which avoid a similar situation developing in the future.

Attached: copies of three letters which are representative of the liaison [illegible]

ORIGINAL CONTACT LETTER SENT TO 30 COMPANIES / ORGANISATIONS

Tel: 01-459 6621 (day)
01-965 4817 (home)

11 We... House Road
... NW10 ...

June 1985

Dear

Optical Engineering Training Places for the
United Nations Industrial Development Organisation

I have been approached by UNIDO to find four training places for optical engineers from India and I am writing to you to ask if you might be interested in being involved.

UNIDO is looking for industrially based training periods of up to 6 months for these people, for which they will pay £200 per week.

The trainees are all in their twenties (the youngest is 22 years old and the oldest is 29 years) and they have all studied optics as a specialisation at a first class technical institute, so they can each be potentially useful temporary members of your development team, if you were to take one of them on.

In particular UNIDO is looking for training places where the trainee is placed with a senior technical person so that they can be treated as a project engineer working under the supervision of that senior person. This arrangement might be of interest to you if you require an extra pair of hands for a few months and you don't mind being paid for it. If you are prepared to provide a more traditional training programme this would also be acceptable.

If you are interested in this proposal, could you please write back to me as soon as possible indicating the type of work that you think you might employ the trainee on, and I will send you details of specific candidates.

The candidates are available to start work as soon as they can be accommodated.

I hope you may be able to help in this matter and I look forward to hearing from you.

Yours sincerely,

J. Maxwell

INSTRUMENTS DESIGN DEVELOPMENT
AND FACILITIES CENTRE

A Project of HARYANA STATE ELECTRONICS DEV. CORPN. LTD.
A State Government Undertaking

Assisted by UNDP/UNIDO

IDDC

STAFF ROAD,
AMBALA CANTT. 133 001

Post Box No. 35
Phones : 21190, 22753, 20730
Gram : INSTRUMENT

REGISTERED.

No.IDDC:CTA:85/9c
4ht July, 1985.

Mr. Jonathan Maxwell,
44, Wells House Road,
London NW10 6EE
United Kingdom

ABSTRACTED LETTER

Dear Mr. Maxwell,

I received your letter dated 19.06.1985 and Jagpal showed me the letter, that you have written to him. Thank you very much for all your efforts to find a suitable placement for our engineers and let us hope, that some positive results will materialize in the end.

I Hope that you have received my cable with the answers to some questions concerning UNIDO's procedure. Here once more are some details:

- A monthly payment could be arranged through the British Council.
- UNIDO will cover all expenditures connected with the trainees as air fare, accommodations and subsistence allowances. In addition reasonable tuition fees will be covered too.
- The training programme is supposed to start some time in September or October, 1985.

Mr. H.R. Dixit is supposed to start from 1.09.1985 a three months training programme at Leningrad with Mr. Butusov. He may afterwards join Vickers Instruments for another three months. I would appreciate it very much if you can get a confirmation from this company, that they are ready to accept him for a three month training. They can mention in the confirmation their conditions too.

Mr. N.K. Jain should mainly gets his training in a production company. However if you feel that Vickers Instruments is the right place and if they are ready to accept two persons for training you may place him also there. Starting date in September 1985 for a period of six months.

Yours sincerely

LIASON LETTER TO VIENNA

01-459 5521 (Day)
01965 4917 (Home)

14 Wells House Road
London NW10 6EE

Mr. D.P. Putnam,
Senior Industrial Development Officer,
Engineering Industries Branch,
Division of Industrial Operations,
UNIDO,
A-1400,
Vienna,
Austria.

7th August, 1985

Dear Mr. Putnam,

Your ref: DP/IND/79/046/11-05/31.9.E

You recently sent me some copies of some UNIDO promotional literature, for which I thank you.

This literature was required to secure training places for engineers from IDDC in Ambala, and I believe you, or someone close to you, is now involved in following up the contacts that have been located. In order that our efforts may be co-ordinated, I am enclosing copies of the relevant correspondence which give names, addresses and details of the candidates that I have matched with them. I hope you can make use of this file.

All the details of my visit to Ambala seem to be falling into place well. I have had some excellent briefing notes from both yourselves, and also Mr. Popov and Dr. Jagpal Singh in Ambala. The domestic situation seems to be in order at that end and I have also come to a satisfactory arrangement with my employer.

Thank you for your part in this.

With best wishes,

Yours sincerely,

JM.

JONATHAN MAXWELL