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ASSISTANCE IN THE DEVELOPMENT OF OPTICAL GLASS

SI/ROM/74/817

ROMANIA

Terminal report

Prepared for the Government of Romania
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of Kapil D. Sharma, expert in the research and development of optical glass

United Nations Industrial Development Organization
Vienna

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Explanatory notes

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

References to "tons" are to metric tons, unless otherwise specified.

References to dollars ($) are to United States dollars, unless otherwise stated.

The following abbreviations are used in this report:

ICPTSCF	Institute for Research and Design in Glass and Fine Ceramics
SIS	Special Industrial Services

ABSTRACT

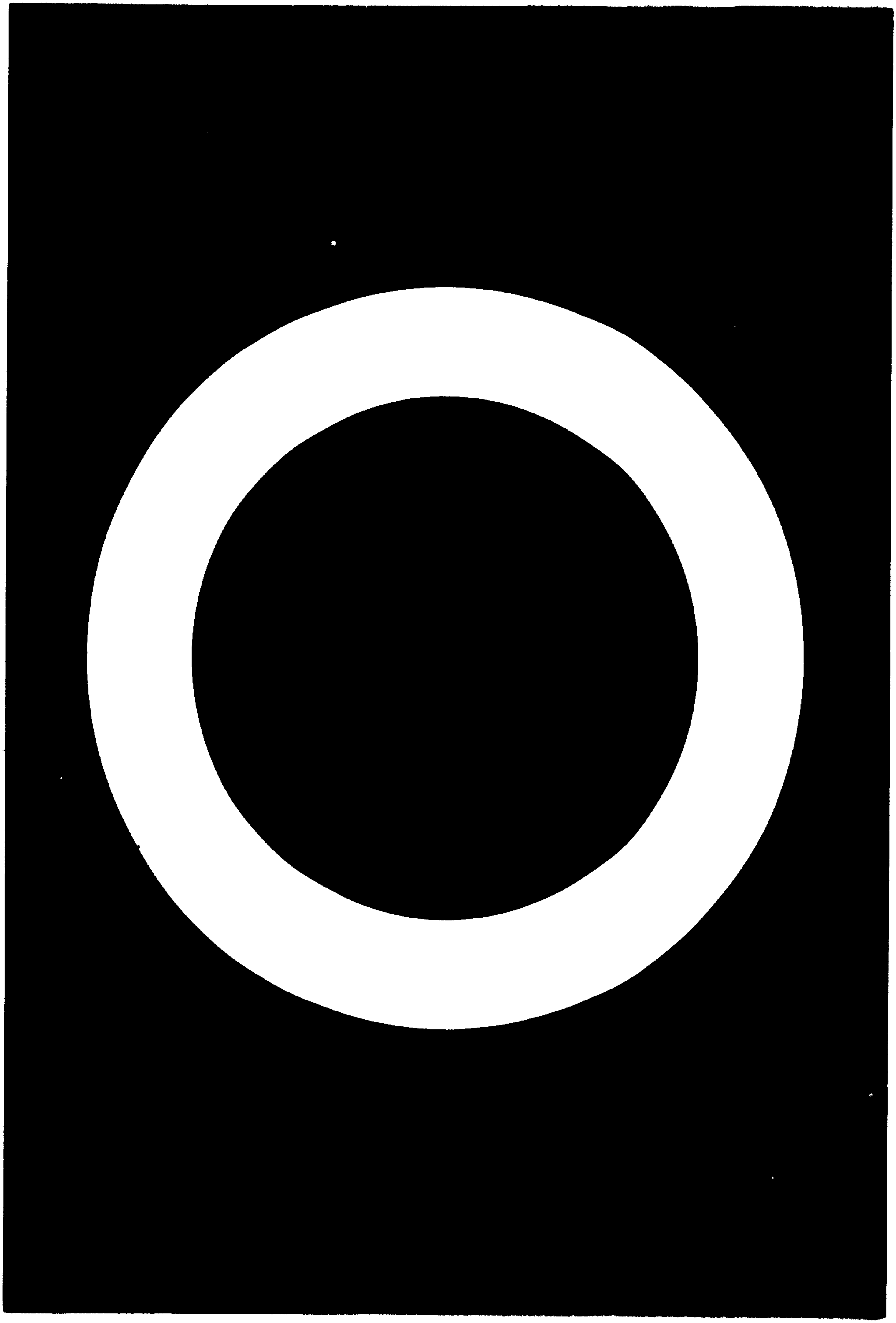
The project entitled "Assistance in the Development of Optical Glass" (SI/ROM/74/817) originated in a request by the Government of Romania in December 1974 for assistance by the United Nations Development Programme (UNDP) in the development of optical glass through intensification of research and pilot plant investigations. The request was approved by UNDP in August 1975, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency and the Ministry of Light Industry as co-operating agency. The seven-month mission was divided into two parts, from May 1976 to August 1976, and from May 1977 to September 1977.

The following conclusions are noteworthy:

(a) The raw materials available in Romania for optical glass production meet the established specifications, with the single exception of barium carbonate, the iron content of which requires improvement;

(b) Romania possesses the technology and know-how required to install a good pilot plant by the first quarter of 1978 to follow up the work of the mission covered by this report.

One of the main recommendations of the report is that UNIDO should provide further technical assistance during the initial stages of operation of the pilot plant, in order to complete the development of the process technology required for the production of optical glass on a semi-industrial scale.



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INTRODUCTION

The techniques of production of optical glass are closely guarded secrets of the few countries in which this material is commercially produced. At present the optical instruments industry in Romania depends entirely on imports to cover its optical glass requirements. The Government of Romania therefore wished to develop its own optical glass industry, and, to this end, in December 1974 made a request to UNDP for technical assistance. The request was approved by UNDP under the Special Industrial Services (SIS) Programme in August 1975, with the United Nations Industrial Development Organization (UNIDO) designated as executing agency and the Ministry of Light Industry as co-operating agency. The two-part seven-month mission entitled "Assistance in the Development of Optical Glass" (SI/ROM/74/817) took place from May 1976 to August 1976, and from May 1977 to September 1977. A budget of $75,000 was alloted, of which $50,000 were earmarked for equipment.

The expert had the following specific tasks to perform:

(a) To study all materials available from the natural resources of Romania and their quality for use in making optical glass;

(b) To advise on the treatment of raw materials for optical glass production and to formulate the different compositions of optical glass for different industries;

(c) To assist and advise on the installation and design of a pilot plant for the production of optical glass and the equipment necessary for high-quality optical glass products;

(d) To assist in writing up the tender specifications for pilot plant equipment for quality control and standardization of the produced glass;

(e) To formulate quality control and raw material specifications for the production of optical glass;

(f) To advise on the different qualifications necessary for optical glass such as chemical, heat and radiation resistance;

(g) To advise on the different aspects of the implementation and establishment of a factory for optical glass, bearing in mind the techno-economic feasibility and profitability at different production levels for the local and export markets;

(h) To examine the local skills and advise on the need for training and further UNIDO assistance.

The major objective of the project was to assist the Romanian Institute for Research and Design in Glass and Fine Ceramics (ICPTSCF) in the development of optical glass through intensification of research and pilot plant investigations.

I. MANUFACTURING OPTICAL GLASS

A. Methods

Optical glass is manufactured only in a few countries, the major producers being the France, Germany, Federal Republic of, the German Democratic Republic, India, Japan, the Union of Soviet Socialist Republics, the United Kingdom and the United States. Production figures are usually not disclosed, but annual world production is estimated at between 15,000 and 20,000 tons. The methods of production are kept closely guarded, but, in general, the following methods are used: melting of glass in ceramic pots; melting in platinum pots; and melting in continuous tank furnaces.

Melting in ceramic pots

A glass batch of a specific composition is melted in a ceramic pot in a gas-fired furnace. The molten glass is stirred mechanically by a ceramic stirrer to obtain homogeneity, and is then either cast in the form of a slab in a metal mould, or rolled in the form of a plate on a metal table, or the pot is cooled rapidly under a cooling can. In the first two processes, the slab or plate is annealed and examined for inhomogeneities and inclusions, and the selected pieces are used for making plates or moulded blanks. In the third process, the pot is broken to obtain chunks of glass which are examined for inhomogeneities and then moulded in the form of random slabs or lens blanks.

The ceramic pot process is suitable for relatively small productions of many varieties of glass. The yield of good glass is usually between 25 and 30 per cent. Ceramic pots are generally not suitable for melting corrosive glasses, like dense barium crowns or rare earth glasses.

Melting in platinum pots

The glass is melted in a platinum crucible either in an electric furnace heated by resistant elements or by high-frequency induction heating. It is stirred by a suitable platinum stirrer to obtain the required homogeneity. Thereafter the glass is cast in the form of a slab which is annealed. In another method, which is semi-continuous, the molten glass is allowed to flow from a platinum tube at the bottom of the crucible in the shape of a continuous strip or bar. This method is generally used for melting special optical glasses and also dense barium crowns and rare earth glasses. The yield of good glass may be between 65 and 80 per cent.

Melting in a continuous tank furnace

This method has been in use since the early 1950s and is suitable for melting large volumes of optical glass. The yield is high, between 70 and 80 per cent. The method is capital intensive, as over 70 kg of platinum is needed for one furnace and the same quantity is required to be carried in stock for repairs and replacement. The method is economical for large-scale production and the plants usually have a number of furnaces to bring down the operating costs and overheads.

The method consists of melting a glass batch in a refractory tank, which is an all-electric or mix-melter type, from which it goes through a riser to a refiner, both of which are lined with platinum and heated electrically. The glass is then stirred by a platinum stirrer and allowed to flow through an electrically-heated platinum tube at a controlled temperature. The glass flowing from the platinum orifice is either sheared into gobs and pressed in the form of blanks of the desired shape and weight, or is allowed to flow continuously into a mould to form a strip, a rod or a block. This method is not suitable for the production of large varieties of optical glass required in limited quantities.

B. Technology

The demand for optical glass in Romania by 1980 is estimated to amount to nearly 100 tons in several types and varieties of glass. Considering the demand pattern and that all the types can be easily melted in ceramic pots, it was decided to base the first industrial plant on the ceramic pot process.

The technology consists of melting glass in a preheated ceramic pot in a recuperative pot furnace fired by natural gas. The melting temperature is between 1350^{o} and 1450^{o}C depending upon the type of glass. The glass is stirred mechanically by a ceramic stirrer to obtain the desired homogeneity and is then slowly cooled to the required viscosity with stirring continued.

During this cooling process, the glass absorbs any undissolved gases, becomes chemically homogeneous, and at the end of the operation is viscous enough to be cast in the form of a slab in a metal mould or to be cooled under a cooling can. The pot of glass can also be cast on a table and rolled in the form of a plate. The cast slab is slowly cooled (annealed) in an electric oven. After a preliminary examination, the slab is cut into four or more pieces which are then critically examined and trimmed into smaller slabs and chunks. During this process all visible cords, striae, bubbles and other inclusions are trimmed off. The selected pieces are then suitably processed by slumping or moulding to form blanks, plates, random slabs and moulded lens and prism blanks. Finally each piece is tested for homogeneity and good pieces are annealed in an electric furnace in such a way that high optical homogeneity is achieved and the birefringence due to strain remaining in the glass does not exceed 10 nm per path of one cm.

C. Raw materials

Batch materials used in making optical glass are required to be of high purity and consistency and to meet certain specifications. The raw materials available in Romania were thoroughly examined and found to meet the required specifications, the only exception being barium carbonate which required improvement in its iron content. Silica sand, which is the major batch material, is prepared by grinding and acid treatment of quartz occurring at Uricani in Romania. Other raw materials are mostly chemicals, like potassium carbonate, potassium nitrate, sodium carbonate, sodium nitrate, borax, boric acid, red lead, zinc oxide, barium carbonate and barium nitrate, which are all locally available. Specifications of all raw materials required for the production of optical glass were supplied to the institute. Thus there should be no problem in the commercial production of high quality optical glass from indigenous raw materials.

However, for making ceramic pots and stirrers, suitable fireclay and plastic clay of the desired composition and purity have not yet been located in Romania. The Institute therefore decided for the present to import their requirements of pots from the Federal Republic of Germany. At a future date they plan to take up a project for the development of pots and stirrers from a blend of suitable indigenous and imported clays. The technology of making pots and stirrers by the slip-casting technique was discussed with the Institute engineers.

D. Pilot plant

Before the expert arrived at ICPTSCF in May 1976, the Institute had set up a small pilot plant at its premises at Bul Ion Sulea for melting optical glass in small ceramic pots with a capacity of 50 l. A larger glass melting furnace capable of taking pots of 350 l had been installed in another pilot station at Militari. A few items of essential equipment, such as a glass stirring machine, cooling cans and a device for casting glass, had been manufactured, and a few experimental meltings had also been carried out. These were however not successful, particularly with regard to the homogeneity of glass. The equipment required for processing, finishing, fine annealing and inspection of glass were not available at that time.

II. PROJECT ACTIVITIES

A. First phase

During the first phase (17 May 1976 to 16 August 1976), development of the following four optical glasses was undertaken with the existing furnaces and equipment:

Type BK - 7:	1.	5167/64.1
Type SF - 5:	1.	6727/32.2
Type SF - 7:	1.	6398/34.6
Type BK - 7R:	1.	5167/64.1

The melting technology of the above glasses was established and glass of satisfactory quality, fairly free from seeds and striae, was obtained. However, as a sufficient number of meltings could not be carried out owing to a shortage of pots and non-availability of a precision refractometer, only compositions of the first two glasses produced according to the required optical parameters could be finalized. The other glasses came very close to the specified values, and their compositions were finalized by ICPTSCF engineers who carried out some more melting during the interval between the first and second phases. The design of the equipment and furnaces not available during the first phase was discussed with ICPTSCF so that these could be manufactured during the expert's absence. In accordance with the UNIDO guidelines, the assignment was carried out in close collaboration with the local engineers to enable them to follow all aspects of the problems concerning the manufacture of high-grade optical glass and to give effect to the recommendations.

B. Second phase

Glass compositions

Compositions of the four glasses mentioned above had been almost standardized before the expert arrived. Some of these glasses were processed during the period of the mission and supplied to the industry in the form of random slabs. The material seems to have been well received by the industry and its quality approved.

In consultation with ICPTSCF, development of the following optical glasses was undertaken during the second phase (1 May 1977 to 31 August 1977):

BaK 4 - R:	1. 5688/56.0
Ø 102:	1. 6170/36.6
SF - 2R:	1. 6477/33.9

The development of the above glasses could not be completed since the melting furnaces at Sulea pilot plant needed extensive repairs and reconstruction and it was not possible to carry out any melting for about two months. Further work on the above glasses could be taken up only after the beginning of pilot operations in late August 1977. Approximate compositions of the above glasses and their melting schedules were discussed with the concerned engineers, and the expert feels that it should be possible for them to develop exact compositions by carrying out a few trial meltings in pots of 350 l. The pilot plant furnace at Militari had also suffered a setback when its chimney collapsed during the March earthquake and the forced draught did not initially give satisfactory results. It would be possible to obtain good glass by making certain changes in the melting technique, but a few trials would be necessary.

Glass casting technique

Several castings of molten glass from small pots were carried out successfully at the Sulea pilot plant. Castings from pots of 350 l would be carried out at Militari plant after suitable metal moulds have been manufactured.

Casting of glass is a very critical process for which the glass melt must be at the right viscosity. For the pots of 350 l, three or four experimental castings would have to be done for each glass in order to finalize the casting schedule. The casting temperature of each glass should be correlated with the high-temperature viscosity data obtained in the laboratory. For most glasses, the viscosity of glass at the time of casting is $10^{3.8}$ poises, while the viscosity for the purpose of cooling the pot under a can is around $10^{3.3}$ poises.

For some glasses, particularly coloured filters, the rolling of molten glass on a metal table in the form of a plate will be a better technique. This has been discussed and ICPTSCF would be in a position to design a rolling table for their new pilot plant.

Annealing of cast slab

ICPTSCF has designed and manufactured a slab-cooling furnace for pots of 350 l, but it has yet to be tried out. Design of another type of annealing furnace and typical annealing schedules were given to the Institute.

Glass-sawing and trimming

A hydraulic press for cutting a slab or a thick plate of glass by cracking it along a line of flaw created by a diamond pencil was designed and partly manufactured. A glass sawing machine and diamond discs received through UNIDO were installed and put into operation. For trimming glass, suitable tools with hardened edges were developed and manufactured.

Slumping of glass

Design of ceramic moulds for slumping of glass and temperature schedules for various glasses were discussed. Borosilicate crown and flint glasses were successfully slumped. Large scale slumping would be possible after the required furnaces have been manufactured.

For slumping of glass, knowledge of its liquidus temperature is essential. A discussion was held concerning a laboratory apparatus to determine liquidus temperature. Typical slumping schedules for some of the glasses were also given.

Moulding of optical blanks

A moulding furnace and a pneumatic press, the design of which was discussed at the Institute during the first phase, were manufactured. These are expected to be installed and tested in September 1977. After successfully operating one unit for some time, new units could be manufactured.

Moulding of blanks is a highly skilled operation. It may be necessary to train two technicians abroad in a firm specializing in moulding of optical blanks or to invite through UNIDO an experienced technician to give training at the plant for 3 months.

Fine annealing

One air-circulating furnace has already been manufactured and is expected to be tried out soon. After trials are conducted more units will be manufactured for the pilot plant.

Annealing temperature and annealing range have to be determined experimentally in the laboratory for each variety of glass. For this purpose, determination of transformation temperature and strain point is carried out on the Linseis dilatometer obtained through UNIDO. The Institute was provided with typical annealing schedules for several glasses.

Inspection and quality control

Striae and bubbles. Apparatuses for detecting cords, striae and bubbles in glass were designed and manufactured. These were put into use while another apparatus for detecting fine striae by shadowgraph test is being manufactured. Each slab or block of glass is critically examined with respect to striae and bubbles and is given a suitable grading.

Optical properties. Each melt of glass is given a separate number and is tested for the following parameters.

The refractive index for 12 or 13 spectral lines is measured to an accuracy of $\pm 1 \times 10^{-5}$ on a Pulfrich type refractometer. The maximum permissible variation in refractive index for a line from melt to melt is ± 0.0010, but for high-index glasses it may go up to ± 0.0015.

From the above determinations, Abbe value V_d and relative partial dispersions are calculated. The maximum variation in Abbe value V_d from melt to melt should generally not exceed $\pm$ 0.5 per cent of Vd.

The coefficient of internal transmittance, i.e. the ratio of white radiant flux at the end to the radiant flux at the beginning of the optical path inside glass 1-cm thick, is determined for each melt of glass. The transmission characteristics of glass vary from melt to melt, as they are dependent upon the glass type and the purity of the raw materials used. For most glasses this coefficient is less than one percent, but for some it may go up to 1.5 per cent. For special requirements it is sometimes required to be even below 0.5 per cent.

Thermal properties. The transformation temperature, TA or Tg, is the temperature at which the viscosity of glass equals 10^{13} poises, and indicates the annealing temperature of that glass.

Thermal expansion per degree centigrade in the intervals of 20° to 100° and 20° to 300° must be given for each type of glass.

Stress birefringence. For normal optical purposes the limits of acceptable birefringence is 10 nm per cm. For special work, the birefringence can be reduced to about 3 nm per cm by following longer annealing schedules.

Resistance to chemical attack. The ability of glass to withstand chemical attack during grinding and polishing operations can be assessed from an acid durability test in which polished samples of glass are exposed to 0.5 N nitric acid. In tropical climates, optical components also have to withstand attack by moisture and the ability of a glass to withstand such atmospheric attack is assessed quantitatively by exposing polished samples to temperature - humidity cycles, each of two hours duration, in a closed and controlled humidity chamber over a period of twel.e days. During each two hour cycle, the temperature is maintained at 60°C for one hour and 45°C for the second hour at maximum humidity. After completion of the test, samples are examined under reflected light and graded according to the extent of visible deterioration of the polished surface.

Standard specifications

The technical and quality requirements of optical glass and methods of grading are described in several standard specifications and also in the manufacturers' catalogues. It is therefore not necessary to go into further details here. It will be useful to procure the following standard specifications for reference.

BSS 4301,1968 (United Kingdom)

DIN 3140,1958 (Federal Republic of Germany)

GOST 3514/67 (Union of Soviet Socialist Republics)

IS 1940 - 1960 (India)

MIL - G - 174A (United States)

III. FUTURE PILOT AND INDUSTRIAL-SCALE PRODUCTION

Installation of a new pilot plant at the Institute

In view of the inadequate space available at the two existing small pilot plants at Sulea and Militari and the impossibility of streamlining the essential operations, the Institute decided to set up a new well-planned and integrated pilot plant at its premises at Sulea. This pilot plant is expected to be completed by 28 February 1978. Until that time development work will continue in the existing pilot stations. The task of the new pilot plant is to work out on a semi-industrial scale the complete technology and parameters required for setting up an industrial plant.

The layout of the new pilot plant and requirements of machinery and equipment, together with their specifications, were discussed in detail at the Institute. A list of items required to be imported was also prepared. Improvements in the design of the melting furnace, cooling cans and the slab annealing furnace were discussed. The technology for shaping chunks of glass into the form of plates required for making moulded blanks and the equipment required for this were also considered.

It is suggested that the Institute should immediately install one unit each of the following equipment and furnaces and test them for performance so that defects and shortcomings, if any, can be corrected before manufacture and installation of additional units.

Fine annealing furnace, air circulating type

Furnace and press for moulding of lens blanks

Slab annealing furnace

Slumping furnace

Design of an industrial plant

Advice was given on the layout of the proposed industrial plant and the machinery and equipment required. A flow sheet, indicating the manufacturing operations involved in the commercial production of optical glass and the estimated yield of glass at each stage, was prepared in order to determine the techno-economic feasibility of the project.

IV. PROJECT REVIEW

The project being under the SIS programme, its objective was limited to evaluation of raw materials, development of a few glass compositions, advice on the equipment required to develop the pilot operations, quality specifications of the material, and the process involved in the expansion of production. These objectives were for the most part achieved during the two missions.

The composition of four glasses was developed and that of three glasses was under development. Samples of glass made in the pilot plant were supplied to the industry and their quality was approved. The process technology required for the production of optical glass on a pilot scale was worked out, although a few operations could not be completed. The equipment required for some of the manufacturing operations was produced while the remaining items are being manufactured. Layout and equipment required for the new pilot plant and the proposed industrial plant were also discussed in detail and finalized.

The above work was carried out in close collaboration with the local engineers to enable them to understand some of the aspects of the complex problems concerning the manufacture of high-grade optical glass. It would be possible for them to follow up the work and install a good pilot plant by the first quarter of 1978. During the period September 1977 to February 1978, they would also be in a position to work out some more glass compositions and processing details utilizing the existing pilot plant and laboratory facilities. However, any rapid progress would be possible only after the development work has been intensified in the new pilot plant under installation. In the initial stages of operating this pilot plant, the Institute would need further technical assistance from UNIDO. The results achieved in the pilot plant will form the basis for the establishment of an industrial plant by 1980-1981.

The equipment already supplied by UNIDO for the project has proved useful and is being well utilized. Recent requests have been made for the provision of a few more items as soon as possible.

In the project budget, fellowship training for two persons was included. It would be helpful if arrangements for this training could be finalized early.

Based on the results achieved through UNIDO assistance provided in 1976 and 1977, the Institute is setting up a new pilot plant for the development of complete process technology for industrial production of optical glass.

Installation of the pilot plant is expected to be completed by 28 February 1978. For the success of the project, the Institute will need further technical assistance from UNIDO in the initial stages of operation of the pilot plant in developing the complete process technology, particularly the following: the technique of casting glass melted in ceramic pots on an industrial scale; the processing of cast slabs to form blocks, random slabs and moulded blanks; and obtaining, as far as possible, maximum yield during each operation in the early stages of a project. Guidance will also be required in the fine annealing and quality control of processed glass.

As the time required to complete one cycle of operations from the melting of one pot of glass to its final inspection takes about six weeks, the minimum period for the above technical assistance should be about 12 weeks, during which major technical problems arising out of the various operations are expected to be resolved to the extent that the follow-up action can be undertaken by the local engineers. This assistance would require a provision of $12,600 in the project budget for 1978.

The Institute would also need further technical assistance from UNIDO in the training of two local technicians in the technique of moulding optical blanks by pressing. The training may be for a period of two months in a plant specializing in moulding of optical lens blanks. If it is not possible to arrange the above training, an experienced technician may be appointed by UNIDO for a period of three months to provide such training to local technicians in the pilot plant at Bucharest. The technical expert should have practical experience in the moulding of optical lens and prism blanks of various shapes and sizes made from different types of optical glass. The estimated cost for the expert would be $12,600 in 1978.

In addition to the advisory and training services mentioned above, further assistance will be required in obtaining some more items of equipment for processing, testing and quality control of optical glass. The extent of assistance required under this head is estimated at $60,000. A list of the additional items required for the project in 1978 is given in the annex.

As already mentioned, the manufacture of optical glass is full of complexities, and many new technical problems arise during the manufacturing operations. It is therefore strongly recommended that the project should be taken up as a regular, long-term project in co-operation with UNIDO, so that the objective of starting industrial production of optical glass in Romania can be achieved. For this purpose technical assistance from UNIDO will be required till the end of 1981. The Institute fully concurs with this recommendation.

For success of the project it is recommended that the Institute should employ three additional young, qualified glass engineers exclusively for the pilot plant work. They will work in shifts and look after details of the various operations. In the production of precision material like optical glass, close attention to details can not be over emphasized.

V. ONE-MONTH EXTENSION OF PROJECT

During the extension period, further progress was achieved in respect of some of the production operations, particularly in the installation and trial operation of a furnace and a press for moulding lens blanks, and in the trial of fine annealing furnaces. Some improvements were also made in the glass-melting furnace at the small pilot plant at Militari, and a few more meltings were carried out with better results.

As mentioned earlier, UNIDO could help to ensure the success of the project by providing further technical assistance in March/April 1978, i.e. during the initial stage of operation of the pilot plant, in developing further glass compositions and process technology on a semi-industrial scale. Technical assistance will also be needed in April 1979 to evaluate the working of the pilot plant for about a year, to suggest further improvements where needed, and to initiate preparation of the detailed project report and the design and acquisition of equipment for the industrial plant. Further assistance will be needed in 1980 and 1981, depending upon the progress achieved. During this period it would be necessary to finalize details of all industrial operations based on the techno-economic data available from the pilot plant and to compile a comprehensive instructions manual for operating the industrial unit. Training of personnel for the new unit will also be taken up.

Budget estimates for 1978, 1979, 1980 and 1981 are given below.

<u>Work programme for the Institute during the period October 1977 to February 1978</u>

(a) Installation of the pilot plant furnaces and equipment;

(b) Laboratory investigations

Complete chemical analysis of the following imported glass samples:

T ∅ 5 and T ∅ 105
K 114

Determination of high temperature viscosity, liquidus temperature and transformation temperature of the following glasses made at the Institute:

BK - 7
BK - 7R

SF - 5

SF - 7

(c) Glass melting

Further melting of BK - 7, BK - 7R, SF - 5 and SF - 7 glasses in ceramic pots at Militari

Trial melting of SF - 2 and F 4 - R glasses in ceramic pots

Trial melting of SF - 4R and SK - 4 glass in small Zac pots

(d) Annealing

Annealing furnace for large cast slabs and fine annealing furnaces - batch type and air-circulating type - may be manufactured and tested for their performance.

Work programme for UNIDO experts during the period March to June 1978

One senior technical expert (project co-ordinator) is required for three months, beginning in April 1978, for the development of pilot plant operations regarding melting, casting, processing and inspection of optical glass of various types, including development of glass compositions, melting schedules and fine annealing achedules. The expert will also have the task of evaluating the working of the pilot plant and assisting in the improvement of the design and operation of furnaces and equipment.

It has been suggested by the Institute that the expert who conducted the mission covered by this report should return as project co-ordinator (senior technical expert) in April 1978 to provide further technical assistance for the project. UNIDO should request the Government of the expert's home country for his release about three months in advance.

Another technical expert is required for three months beginning in April 1978 for the training of personnel in the moulding of optical glass lens and prism blanks, including the design of moulds and the testing of moulded products, and also the trimming of rough glass and the preparation of glass plates required for making moulded blanks. The expert should be a glass technologist or chemical/mechanical engineer with adequate practical experience in the moulding of optical blanks. He would have the tasks of designing equipment and moulds for pressing lens and prism blanks of various shapes and sizes from optical glass, training personnel for trimming and moulding of optical glass for industrial production, and testing finished products.

Project budget estimates for 1978

Components	Duration	Cost ($US)
Project personnel		
Project co-ordinator (senior technical expert in development and production of optical glass)	3 m/m	12,600
Technical expert in moulding of optical glass lens and prism blanks	3 m/m	12,600
Equipment		60,000
Total		85,200

Project budget estimates for 1979

Components	Duration	Cost ($US)
Project personnel		
Project co-ordinator (senior technical expert in development and production of optical glass	3 m/m	13,600
Technical expert in design and operation of equipment for production of optical glass	3 m/m	13,600
Equipment		40,000
Fellowship training	4 m/m	5,000
Total		72,200

Project budget estimates for 1980

Components	Duration	Cost ($US)
Project personnel		
Project co-ordinator (senior technical expert in development and production of optical glass)	2 m/m	10,000
Technical expert in operation of equipment and furnaces for production of optical glass	3 m/m	15,000
Fellowship training	4 m/m	5,000
Total		30,000

Project budget estimates for 1981

Project personnel	Duration	Cost ($US)
Project co-ordinator	2 m/m	10,000
Equipment		20,000
Total		30,000

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. The raw materials available in Romania for optical glass production meet the established specifications, with the single exception of barium carbonate, the iron content of which requires improvement.

2. Romania possesses the technology and know-how required to install a good pilot plant by the first quarter of 1978 to follow up the work of the mission covered by this report.

3. In the further development of optical glass process technology, technical assistance will be required, particularly in the following areas: the technique of casting glass melted in ceramic pots on an industrial scale; processing the cast slabs to form blocks, random slabs and moulded blanks; fine annealing and quality control of processed glass; and obtaining, as far as possible, maximum yield during each operation.

B. Recommendations

1. Further technical assistance should be provided during the initial stages of operation of the proposed new pilot plant, in order to complete the development of the process technology required for the production of optical glass on a semi-industrial scale. For this purpose, the Institute could be provided with the services of a technical expert for three months in the first half of 1978, and of another expert in the moulding of optical blanks for three additional months, also in the first half of 1978.

2. The Institute should secure the services of three new qualified glass engineers exclusively for the pilot plant work.

3. The project should be taken up as a regular long-term project in co-operation with UNIDO, so that the objective of starting industrial production of optical glass in Romania can be achieved. For this purpose, technical assistance from UNIDO would be required until the end of 1981.

Annex

EQUIPMENT SUPPLIES

A. Major items of equipment received through UNIDO in 1976 and 1977

Equipment	Approximate cost in dollars
Linseis ' dilatometer together with accessories	7,700
Diamont Boart glass-sawing machine with 2 diamond discs	1,400
Allgaier ' tumbler screening machine and accessories	6,000
Platinum crucible with stirrer	5,200
Multipol Mark II ' precision polishing machine, with accessories	4,300
Hartmann Braun optical pyrometer	2,700
Super Kanthal heating elements	1,700
Other items	1,000
Total	30,000

B. Further items of equipment requested from UNIDO in 1977

Jenoptik precision goniometer spectrometer with accessories	4,500
Accessories for Multipol MK-II precision polishing machine	2,500
Accessories for 'Jenoptik' precision refractometer PR-2	200
Oriel optical accessories	1,800
Total	9,000

C. Additional items required for the project in 1978 (cost not known at present)

Rotovisko for determining high temperature viscosity of glass

IR spectrometer, range 1 to 3 micron

Universal milling machine

Electric hoists of capacity 0.5 ton, 1 ton and 2 ton

Kanthal ' heating elements

Oxygen analyser and recorder for furnace flue gas analysis

Instrument for measuring small pressures in furnaces

Apparatus for calibration of thermocouples and optical pyrometers

EEL Light Master

Apparatus for determining stress optical coefficient of glass

C-721

79.01.15