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Strengthening the Capability of the Syrian Scientific Studies and Research Centre in the Field of Optical Technology

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Syrian Arab Republic

Technical Report:

Requirements of the Construction of a Unit for Melting Glass for Optical Instrumentation

Prepared for the Government of Syrian Arab Republic by the United Nations Industrial Development Organization Acting as Executing Agency for the United Nations Development Programme

Based on the work of Dr Wolfgang Heindorf, consultant in glass technology for optical instrumentation

United Nations Industrial Development Organization

Vienna

1. Contents

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2. Explanatory notes

Currency:	Syrian pounds (LS)
Exchange rate:	1 US $ = 11.10 LS

3. Abbreviations used in the report

UNIDO	-	United Nations Industrial Development Organization
UNDP	-	United Nations Development Programme
SSRC	-	Scientific Studies and Research Centre, Damascus, Syria
SAR	-	Syrian Arab Republic

3. Recommendations

3.1. Based on the potential demand of optical glasses used in the construction of optical instruments for schools, high schools and scientific institutes as well as considering the increasing demand especially in public health, research and development laboratories and industries, the establishment at SSRC of a glass facility devoted to research design and development and limited production is recommended.

3.2. The mode of production of optical glass is recommended as discontinuous melting; this approach is suggested because of the present quantity requirements in quantity and glass types with scope of further enlargment upon increased demand.

3.3. In coordination with the existing production facilities in SSRC it is recommended to establish the glass facility in two scales:
- melting unit for 1 litre scale,
- melting unit for pilot production for 80 litres scale.

3.4. To guarantee the high quality of glass as well as the facility for melting different glass types within one melting unit it is recommended to perform melting in platinum crucible.

3.5. To guarantee the production of optical glass according to international standards, the import of specified raw materials is necessary. Local raw materials presently used for mass glass production in Syria and other indigenously available materials like heat-resistant stones, shall be utilized to the maximum possible extent.

3.6. To minimize the expenses in the beginning of glass production, the equipment and resources available at SSRC

and glass factories are recommended to be used to fullest possible extent.

3.7. During initial phases, the glass production is recommended to start with melting of crown and flint glasses. For special optical glasses with extreme performance and quality, import is advised presently.

3.8.1. For the development of a pool know-how and technology, the training of engineers, technicians and skilled workers should be performed abroard.

3.8.2. For clear appreciation of the optical glass melting process technology, it is considered necessary and advisable to arrange study tour of national team project to advanced countries.

3.9. For initiation of the proposed glass facility, the cooperation with foreign specialists should be guaranteed.

3.10. To guarantee the function and technology of the proposed glass facility, the preparation of a detailed project report by one of the international leading manufacturers of glass is recommended.

3.11. For meeting immediate requirements of the country, there is a reasonable case to establish indigenously in addition ophthalmic glass blanks manufacturing facility. UNIDO might like to look into this aspect as well, and arrange for preparation of separate technological report covering specifically vision optics.

4. Terms of reference

The terms of reference consist in the advice on the field of glass technology for optical instrumentation. In detail the following data and future tasks have to be worked out in close cooperation with the specialists of SSRC:

- Assessment of the technical level of the glass industry in Syrian Arab Republic.
- Evaluation of the volume of optical glass, to be produced in the country.
- Determination of the glass sorts required for the instrumentation.
- Investigation of the availability of local resources of raw materials for the anticipated demand.
- Advice on the technology suitable for a small-scale production.
- Drafting of a process chart of the activities to be carried out in order that all requirements can be met under the present conditions.
- Advice on the equipment necessary for the production of glass.
- Estimation of the demand for manpower and the level of qualification required for the installation and commissioning of glass melting units.

The results and recommendations are to be presented in the final report. They shall be the base of the future UNIDO project for the installation of a small-scale production of optical glass.

5. Assessment of the technical level of the glass industry and the infrastructure

In Syria several glass factories have been built because there was a demand for glass products in ordinary life. By using domestic raw materials and recycling glass, the factories in and around Damascus produce flat glass and container glass - in Kaddam glass works - and lamp-shades and drinking-vessels - in Doummar glass works.

Flat glass, safety glass, container glass, and illuminating glassware are produced in Aleppo glass works.

The industrial equipment was imported in part from industrially advanced countries, especially from France, and comes up to the international level of development.

In Kaddam glass works also a sand preparation plant (classifying and cleaning plant) and a centrally controlled batch house are operated. The glass works are equipped also with the measuring devices required for their individual products.

The existing melting capacities do not constitute, however, a basis for the installation of an optical glass melting facility. But specialized equipment, raw materials (Na_2CO_3, AlO/OH, Pb_3O_4), and measuring devices can, of course, be utilized in order to facilitate the start.

In the country itself numerous branches of industry were established or are under construction where precision mechanical-optical instruments are necessary for the quality control and for raising the performance characteristics.

In order to support such a development, extensive training and upgrading possibilities were organized. In the schools and during the studies of more than 200,000 students numerous precision mechanical-optical instruments are wanted badly.

In order to provide such an instrumentation, SSRC has estab-

lished a manufacturing location for lenses and prisms. By using imported glasses SSRC enables selected glass components to be provided for the instrument manufacture.

As a result of the demand alone from the educational system and the requirements arising from the health care system as well as the already existing branches of industry such as the building-material, textile, and pharmaceutical industries, an ever bigger amount of scientific-technical instruments must be made available.

Owing to the limited world optical glass potential it is advisable to build up melting capacities of one's own as a necessary future development.

6. Evaluation of the volume of optical glass to be produced in the country in order to meet the current and future needs of optical instrumentation facilities

According to an annual statistical report

1,741,800	lenses
72,800	prisms
103,400	projector lenses, and
314,400	microscope lenses

are required in SAR every year.

Hence it follows a net glass amount of

1,741,800	x	20 g	average weight/lens	=		34,836 kg
72,800	x	36 g	average weight/prism	=		2,621 kg
103,400	x	80 g	average weight/projector lens	=		8,272 kg
314,400	x	5 g	average weight/microscope lens	=		1,572 kg
						47,301 kg

With a yield of

40 %	a glass quantity of	118,252 kg
50 %	a glass quantity of	94,602 kg
60 %	a glass quantity of	78,835 kg

has to be produced.

7. Determination of the specifications of glass sorts needed for optical instrumentation applications

The following glass sorts are required for the optical instruments to be manufactured by SSRC:

	Refractive Index n_d	Abbe Number ν_d	Density g/cm^3
Crown glasses			
K 3	1.518216	58.99	2.55
K 13	1.524206	58.62	2.53
Boron crown glass			
BK 7	1.516664	64.06	2.53
Phosphate dense crown			
PSK 3	1.552324	63.49	2.91
Barium light crown			
BaLK 3	1.51835	60.03	2.63
Barium flint glasses			
BaF 4	1.605616	43.94	3.50
BaF 5	1.607291	49.31	3.54
BaF 7	1.608011	46.20	3.54
Flint glasses			
F 1	1.62588	35.6	3.68
F 5	1.604373	38.15	3.46
F 10	1.62364	36.7	3.61
Dense flint glasses			
SF 5	1.672704	32.24	4.09
SF 12	1.64831	33.8	3.72
SF 13	1.740762	27.71	4.36
SF 14	1.761840	26.53	4.55
SF 15	1.698954	30.06	4.07

8. Investigations of the availability of local recources of raw materials for the anticipated demand

8.1. Raw materials required

For melting the glass sorts mentioned under item 3., the following raw materials are required:

- Quartz powder	SiO_2	SiO_2
- Boric acid	H_3BO_3	B_2O_3
- Phosphorus(V) oxide		P_2O_5
- Soda	Na_2CO_3	Na_2O
- Sodium nitrate	$NaNO_3$	Na_2O
- Potash	K_2CO_3	K_2O
- Saltpetre	KNO_3	K_2O
- Lime	$CaCO_3$	CaO
- Barium carbonate	$BaCO_3$	BaO
- Barium nitrate	$Ba(NO_3)_2$	BaO
- Zinc oxide	ZnO	ZnO
- Hydrous aluminium oxide	$AlO(OH)_3$	Al_2O_3
- Titanium(IV) oxide	TiO_2	TiO_2
- Red lead oxide	Pb_3O_4	PbO
- Arsenic(III) oxide	As_2O_3	As_2O_3
- Antimony(III) oxide	Sb_2O_3	Sb_2O_3

These raw materials must meet the quality requirements "ultrapure, for optical purposes"; i. e. the proportions of colouring components such as Fe_2O_3 or Cu, Ni, Mn, Cr and Co must be extremely low.

The Fe_2O_3 content of the raw materials should amount to only approx. 0.001 % and the content of other colouring ions to only 0.0001 %.

8.2. Data of constituent concentrations in the glass types

Serial Number	Glass Type	SiO_2	B_2O_3	P_2O_5	Na_2O	K_2O	CaO	BaO	ZnO	Al_2O_3	TiO	PbO	As_2O_3	Sb_2O_3
1.	Crown glasses	65-75			5-10	5-10	5-10						+	
2.	Boron crown glasses	50-70	10-20		10-20	+	+	+		+			+	
3.	Phosphate dense crown		5-10	60-70	+	+	+			+				
4.	Barium light crown	60-70	10-20		+			5-15	+				+	
5.	Barium flint glasses	30-50	5-10		0-10		+	10-40	+	+	+	5-10	+	
6.	Flint glasses	25-35	5-25		+	+			5-15			25-55	+	
7.	Dense flint glasses	25-50			+					+		50-70		+

The concentration data apply to all glass sorts of the specific glass type.

Raw materials denoted by + are present in only a few percentages (3-7 %) in the specific glass type.

The refining agents As_2O_3 and Sb_2O_3 are added in concentrations of 0.2 - 1.0 %.

8.3. Determination of the raw material quantities required

When calculating the demand it is assumed that 80-l melts are performed.
Moreover it is implied that the glass quantity per glass sort is uniformly distributed (resulting in an average density of 3.45 g/cm^3).

With a pilot production approx. 35 melts/year can be carried out (1 melt per week owing to melt preparation, melt execution, cleaning of crucible annealing). When melting in the 80-l crucible the effective volume is 72 l. Therefore the average glass quantity obtainable per melt is 250 kg.

Accordingly, the total annual quantity obtainable in a single melting unit is 8750 kg.

For melting this glass quantity the following raw material amounts are necessary:

	Factor	
Quartz powder	1.002	3800 kg
Boric acid	1.776	1350 kg
Phosphorus(V) oxide	1.000	900 kg
Soda	1.710	1000 kg
Sodium nitrate	2.743	300 kg
Potash	1.467	300 kg
Saltpetre	2.147	170 kg
Lime	1.785	700 kg
Barium carbonate	1.287	500 kg
Barium nitrate	1.705	200 kg
Zinc oxide	1.002	250 kg
Hydrous aluminium oxide	1.180	300 kg
Titanium(IV) oxide	1.000	50 kg
Red lead oxide	1.024	1450 kg
Arsenic(III) oxide	1.000	50 kg
Antimony(III) oxide	1.000	50 kg

8.4. Raw material situation

These raw materials do not occur naturally in the required quality in this country.
As a chemical industry is missing they cannot be prepared or produced in SAR.
At present, therefore, the raw materials must be imported from abroard.
This is justifiable considering the relatively small quantities.
As some raw materials are already imported in large quantities and with the required quality, too, for the existing glass industry, these can be used as well.

9. Advice on the technology suited for the small-scale production of optical glass on the base of the state of the art in this field

In view of the aim to set up a production line satisfying the anticipated demand, the range of glass sorts to be melted, the small number of experienced workers, and the capital expenditure to be considered, an experimental melt and a scientific pilot production within a technological centre should be aimed at.

Among the numerous technological processes the discontinuous melting in a platinum crucible heated electrically in a pot furnace is to be preferred.

This approach provides all required conditions such as

- the possibility of melting different glass sorts in a single melting unit,
- satisfaction of the demand by taking into consideration the differential orders of magnitude,
- guaranteeing of a reproducible quality by strict observance of the technological regime,

- low expenditure on the space built-in and the service system,
- minimum expenditure on auxiliary attachments, with a systematic enlargement and completion being possible,
- quaranteeing of a minimum expenditure of skilled manpower for the melting of all glass sorts.

9.1. Description of the technological course

The discontinuous melt for scientific tasks in the medium-frequency furnace (1 l) and the pilot production in the platinum crucible holding 80 (35) l in the pot furnace are the bases of the process.

9.1.1. Batch preparation

To begin with, the raw materials are analyzed qualitatively and quantitatively.
By means of the oxide proportions (factors) determined the batch composition is calculated.
After that the individual raw material amounts are weighed into a trough; then they are mixed thouroughly in a compulsory mixer.

9.1.2. Melting of glass

The batch is filled at melting temperature into the platinum crucible and melted down. This procedure is repeated until the crucible is full.
After that the temperature is raised in order to refine the molten glass.
After a short cooling-down period the stirrer is moved in at a somewhat decreased temperature, and the homogenization begins at an increased rate of rotation of the stirrer. Depending on the viscosity, the stirring rate is continuously slowed down with the decreasing temperature, until the casting temperature is reached.

9.1.3. Casting of glass

When the casting temperature has been reached, the platinum crucible together with the protective refractory crucible is moved manually out of the furnace by means of a fork lift truck and is transferred on to a casting stand. By tilting slowly the crucible and stand the casting mould is filled.

9.1.4. Annealing of glass

The filled casting mould is transferred to the lehr or the annealing hood, respectively. In conformity with a defined annealing schedule the temperature is lowered slowly to the ambient temperature. The glass being now free of stress will be processed further by cracking, saw cutting, grinding and polishing.

10. Flow chart of the activities to be carried out in order to meet all requirements under the actual conditions in the country, including the existing infrastructure, the labour availability, the institutional activities in this and neighbouring fields, and the economic situation

- Elaboration of a concrete project by a general contractor
- Confirmation of the project as the decision on principle
- Purchasing of the know-how and technical documentation for the process and technology of glass melting
- Formation of a project management for the realization of the project
- Provision of the necessary accomodations including the service system

Procurement of equipment (minimum technical equipment)

- 1-l melting unit
  (medium-frequency melting furnace, switch cabinet with me-

dium-frequency generator, stirring machine with platinum stirrer, temperature measuring device with Pt-Pt/Rh thermocouple, exhausting plant)

- 80-l melting unit
  (melting furnace, switch cabinet with transformer, 80-l platinum crucible, protective refractory pot, kanthal-alloy heating elements, stirring machine with platinum stirrer, temperature measurement by means of a thermocouple, exhaust system)

- Batch mixer with troughs

- Transportation mean 500 kg

- Tilt casting machines and moulds

- Temperature-controlled annealing hood

- Procurement of raw materials

  Performance of analyses
  Importation of raw materials
  Organization of co-operative relations with the glass factories in Damascus and Aleppo
  Cooperation with other institutions

- Training of manpower installing and commissioning the production and measurement equipment

This minimum technical equipment constitutes the basis of the melting facility. For this the support of UNIDO in terms of a sequential project is imperative. The complete final state specified exactly and in detail under item 11., is to be reached later step by step.

11. Advice on the appropriate glass-producing and control equipment to be purchased, and the manpower upgrading programmes to be organized in order to establish the operating facilities

11.1. Specification of the rooms including equipment and machines as well as testing and auxiliary installations

Room No.	Designation of Room	Equipment	Number
11.1.1. Production rooms			
001	Raw material store-room	Pallet racks	50
		Electric fork trucks	1
		Lift truck	1
		Samplers	2
		Top-pan balance 10 kg	1
002	Store-room for poisons	Top-pan balance 5 kg	1
		Poison safes	2
003	Batch room	Pallet racks	2
		Steel shelf	1
		Laboratory ball mill	1
		Box sieves	5
		Troughs	20
		Top-pan balance 1 kg	1
		Top-pan balance 10 kg	1
		Table balances	2
		Floor balances	2
		Batch mixers	2
		Industrial vacuum cleaner	1
004	Platinum safedeposit	Racks	2
005	Melting and annealing room	Pot arch	1
		Melting furnace	1
		Vertical stirring machine	1
		Horizontal stirring machine	1

Room No.	Designation of Room	Equipment	Number
		Tilt casting machine	1
		Moulds	25
		Annealing hoods	4
		Electric fork truck with heat shield	1
		Crane system	1
		Sand-blast machine	1
		Radiation pyrometer	1
		Platinum equipment: Crucibles	2
		Stirrers	2
006	Control-engineering room	Switch cabinets for furnace	1
		Switch cabinets for annealing	2
		Control engineering unit (6 colour pen recorders)	1
007	Finishing shop	Cut-off saw with rolling table	1
		Table cut-off saw	1
		Mill saw	1
		Cracking device	1
		Scratching device	1
		Lift truck	1
		Crane system	1
		Diamond cut-off wheels	15
008	Control room	Abbe refractometers	2
		Bubble counter	1
		Striascope	1
009	Sample-machining room	Glass grinding machine	1
		Polishing machine	1
		Blocking table	1
		Workshop goniometer	1
		Surface testing device	1
		Measuring tools	

Room No.	Designation of Room	Equipment	Number
		Abrasive and polishing compounds Pitches and adhesives	
010	Platinum cleaning room	Platinum cleaning plant Chemicals (hydrofluoric acid, neutralizing agents)	1
011	Store-room for raw glass	Pallet racks	30
012	Area for emulsification machine	Emulsification machine	1
013	Area for air-conditioning system, ventilation and deaeration		
014	Manual fabrication of blanks	Heating furnace Pressing unit Fine annealing furnaces	1 1 2
	11.1.2. Workshops		
015	Electrician's workshop Store-room	Shop equipment Racks	
016	Mechanic's workshop Platinum workshop	Shop equipment	
017	Control-engineering workshop	Shop equipment	
018	Waste-air central station		
019	Switching station		
020	Store-room for auxiliary means of production		
	11.1.3. Measuring and testing laboratories		

Room No.	Designation of Room	Equipment	Number
021	Transmission measurement room	Spectrophotometer	1
022	Room for calculating refractive index and stress birefringence	Precision goniometer	1
		Pulfrich refractometer	1
		Stress measuring device	1
023	Chemical laboratory	Laboratory tables	4
		Titration table	1
		Exhaust system	1
		Drying ovens	2
		Heating furnace	1
		Shaking machine	1
		Laboratory glassware	
		Chemicals	
024	Sample-preparation room	Laboratory ball mill	1
		Laboratory disk vibratory mill	1
		Laboratory mortar grinder	1
		Vibrating test-sieve plant	1
		Fine balance	1
		Digital pH meter	1
025	Room for trace analysis	Spectrophotometer	1
		Flame photometer	1
		Atomic absorption spectro-analysis instrument	1
		Table centrifuge	1
		Atomic emission spectro-analysis instruments PG 52, UBI 2, SP 3, MD 100)	1 each
		Spectroscopic carbon	
026	Room for testing chemical resistance	Air-conditioning cabinet	1
		Citoval stereoscopic microscope	1

Room No.	Designation of Room	Equipment	Number
		Drying oven	1
		Extraction columns	5
		Circulating thermostat	1
		Electric water bath	1
027	Photographic laboratory	Photographic-laboratory equipment	1
		Refrigerator	1
		Circulating thermostat	1
028	Store-room for chemicals	Racks	
029	Store-room for samples	Racks	

11.2. Training of personnel for the installation and commissioning of the production, processing, measuring and testing equipment

Education	Specialized vocational training
Chemist	Training in raw-material analysis and final-product quality control
Machine-building engineer	Training in the construction of units and machines
Chemical engineer	Training in the preparation of batch and in glass melting
Physicist	Training in the annealing of glass
Electrical engineer	Training in the assembly and maintenance of electrical systems
Chemical technician	Training in the measurement and quality-control laboratory
Civil engineer or building site technician	Training in furnace lining and the machining of refractories, in maintenance and supervision of the furnace operation
Technician	Training in the cutting-off, grinding and polishing of glass
Electrical technician/Electronician	Operation and Maintenance of the control-engineering system

For running the pilot production approx. 40 workers - melters, laboratory assistents, and craftsmen - are required.