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U . N . I . D . O

MONTREAL / PROTOCOL

SCIMPOS

PHASING OUT CFC 11

Avril 1997

INTERNATIONAL TIERS CONSULT

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SUMMARY

PROJECT COVER SHEET

Country:	Cameroon
Project Title	**Phasing out CFC 11 at SCIMPOS**
Sectors Covered:	Flexible polyurethane foam
ODS Use in Sector	250 MT of CFC 11 in 1996 for Flexible PU Slabstock
Project Impact:	Phase out of annual consumption of 120 MT CFC-11 in the production of flexible slabstock foams.
Export to non-Article 5 countries:	Nil
Foreign ownership:	Nil
Project Duration:	12 months
Project Economic Life:	10 years
Total Project Cost:	US$ 649,000
Implementing Agency's Overheads (13%):	US$ 84,370
Proposed MF Financing:	US$ 733,370
Cost Effectiveness:	5,40 US$/kg
Counterpart Enterprise:	SCIMPOS
Implementing Agency:	United Nations Industrial Development Organization (UNIDO)
Coordinating Ministry:	Ministry of Environment & Forestry, Cameroon

PROJECT SUMMARY

This project will phase out 100 per cent of CFC-11 from the production of flexible slabstock foams used for the production of foam filled mattresses at **SCIMPOS**. The chosen replacement alternative is Liquid Carbon Dioxide (LCD), a method of blowing low density foam utilizing Liquid Carbon Dioxide as a blowing agent. The project will be implemented through modification of existing production facilities and installation of supplementary safety equipment and instruments.

I BACKGROUND

1.1 Sector Background

Cameroon ratified the Montreal Protocol on 28 November 1989 and London Amendments on 6 September 1992. Under Article 5 of the Protocol, Cameroon qualifies for 10 years delay in the phase-out of CFCs and assistance from the Multilateral Fund of the Montreal Protocol (MFMP).

Cameroon does not produce ODS, but there are numerous users of ODS in the country. The ODS are imported either directly by the factories that use them in their production. Most of the ODS are imported from Europe.

The bulk of the ODS are used in the manufacturing of rigid and flexible polyurethane foams and as refrigerants in compressors for domestic refrigerators, air conditioners, and commercial cold storage.

The subsector for domestic refrigerators and freezers in Cameroon consists of two large manufacturers FAEM and U.C.E. The sector of flexible foam is also represented by 2 companies based in Douala, SONOPOL and SCIMPOS. The total ODP consumed in Cameroon more than 500 MT, in 1996 composed of CFC 11, CFC 12, HCFC22, Methyl Bromide and Halons.

Cameroon does not produce CFCs. According to the amended country programme the total consumption of CFCs in the production of polyurethane foam was about 500 MT in 1996. This figure reflects most probably only the import of pure CFC11 and does not consider that the majority of CFC 11 was imported to Cameroon already premixed inside the polyol compound of the polyurethane foam material; the actual CFC 11 consumption in Cameroon is much higher than the figures reflected in the first country programme. The demand of ODS at the moment is stagnant, but it is estimated that it will increase in the future again if the conversion will not be made.

Furthermore due to conversion plans of FAEM and U.C.E. to non CFCs no CFC11 and 12 were imported for the 2 companies in 1996.

Cameroon plays an important role inside the Central African Customs and Economic Union (UDEAC) countries: Cameroon, Gabon, Congo, Central African Republic, Chad, Equat. Guinea; Cameroon exports a significant part of its production to these countries.

Moreover some of the quantities of flexible foam put on the market for local consumption are exported indirectly through other commercial arrangementsThe sub-sector for flexible foams in Cameroon consists of 2 main manufacturers, namely SONOPOL and SCIMPOS who are responsible for the ODS consumption of CFC-11 in the sector of flexible polyurethane manufacturing. The primary product produced, flexible polyurethane foam, is consumed in the local market with some export to the neighbouring countries. The product is mainly used in the production of soft furniture, upholstery, mattresses.

CFC-11 and CFC-12 have been the dominant ODS used in Cameroon. Only CFC-11 is used as a blowing agent in the manufacturing of rigid insulation and flexible cushioning PU-foam.

Primary chemical companies importing polyurethane chemicals to Cameroon for the flexible foam market are: Enichem - Italy, Dow Chemicals - Belgium, Bayer Ag - Germany, Rhone-Poulenc - France, Arco Chemicals - France, Repsol - Spain.

1.2 Company's Background

The company SCIMPOS (Société Camerounaise d'Injection et de Modelage des Produits Organiques et Synthétiques) was established in 1967 and started production in 1969 with the assistance of the French company Rhone-Poulenc. The technical agreement with Rhone-Poulenc stopped in 1991. The company is based in Douala, Cameroon near the Air Liquide plant. It is a privately owned company from the group METOUCK. SCIMPOS is involved in the production of flexible foam used in upholstery and furniture industry. SCIMPOS is also involved in the production of which is not considered in this project.

SCIMPOS has around 100 employees, 10 of them being at management and technical level.

The installed annual capacity of the plant is 2000 MT flexible slabstock PU-foam. Currently 1200 MT per annum is being produced. The production of foam of the last years reads as follows:

1992	1185 MT	1995	945 MT
1993	1012 MT	1996	1011 MT
1994	933 MT		

The company manufactures mainly flexible foam for the furniture and mattress industries.

Company established its production facility with the installation of a conventional, three paper (1 x bottom and 2 x sides) sloping conveyor type slabstock machine, purchased from Viking Engineering Ltd., UK. Maxfoam F-8 (350) slabstock foaming machine purchased from Beamech, UK.

At present SCIMPOS annual CFC-11 consumption is as follows: 120 MT in the continuous slabstock production.

Since low density foam is and will be the important and growing part in the future, a blowing agent is required.

SCIMPOS is prepared to phase out ODS as soon as the new technologies have been acquired, the necessary machinery and equipment installed and the technical staff trained.

Among the technological options currently available on a commercial basis and in line with the established policy of Cameroon to phase out the use of ODS, the company has chosen to replace CFC-11 by liquid carbon dioxide system in flexible PU-slabstock manufacturing.

Due to the relatively high CFC-11 consumption for the flexible foam manufacturing, SCIMPOS decided to avoid the use of any transitional substance and to introduce carbon dioxide and n-pentane as an ultimate solution to meet the country's policy and strategy requirements related to the ODS phase out.

In order to ensure that no production is lost during the installation and commissioning of the new technology, it has been agreed that SCIMPOS will continue using their existing mixing head, metering units, conveyor, paper systems, enclosure, ventilation and controls until the entire new system is installed.

Summary of Existing Equipment and Function

The Beamech (360) is a 360 kg/min, maxfoam type slabstock machine. This production method is quite different from the conventional sloping conveyor machines. The block shape produced is squarer and has a thinner bottom skin than the conventional one. Chemicals are metered to a fixed position mixing head either mounted above what is known as the fallplate section or inverted and mounted on the operator platform at the back of the machine. The mixed and reacting chemicals are delivered to a steel open topped container known as a trough, via flexible hoses. The trough is mounted on top of a beam carrying the first of the fallplates. The reacting foam fills up the trough from bottom to top and spills over into the bottom paper which is supported by the first of a series of fallplates. At this point, the side papers are introduced. The purpose of the fallplates is to try and mimic the rise profile of the foam in such a way that the use of gravity assists in the shaping of the top surface of the block. Therefore, as a general rule, the height of the trough is set at 70 % of the eventual block height. The reacting and expanding foam then flows downwards for 70 % of its rise and only expands vertically by 30 %. After the fallplates, the expanded foam passes onto a horizontal slat conveyor and the fallplate is enclosed by steel side walls. Typically the economics of the process are such that a saving of 6 % is obtained over the conventional machine producing domed blocks.

Storage facilities

Bulk storage area consisting of the following:

Polyol	6 x 20 MT uninsulated bulk storage tank Temperature conditioned drum storage area in the same location as the run tanks.
TDI	4 x 22 T uninsulated drum storage area.
CFC-11	1 x 20 T steel pressure vessel.

Run Tanks

Consisting of the following:

Polyol	1 x 20 MT all insulated and equipped with heating and cooling.
TDI	2 x 6 MT, both insulated and equipped with heating and cooling.
CFC-11	1 x 1800 l
Additives:	2 x 1200 l stainless steel tanks

Paper Systems

A three paper system is used with a bottom paper turn up of between 10-15 mm. Two sides and one bottom paper rewind system is used. The three feeding supports have brake arrangements for keeping an even tension during foaming.

Mixing Head - From ABB - France

Consisting of a fixed position inverted high pressure seven component mechanical mixing system. The inverted head is located on the operator platform and has two flexible hoses connected between it and the trough.

Metering units

Consisting of 8 low pressure pumps equipped with manometers from 10 to 100 bars

Polyol	Single pump high pressure system Bosch.
TDI	Single pump high pressure unit Bosch.
Stannous Octoate	Single pump high pressure system, with positive displacement meter.
Water	Single pump high pressure system, Hydromatic.
Amine	Single pump high pressure system, Hydromatic.
Silicone	Single pump high pressure system
CFC 11	Output 30 kg/min, Bosch 10 cylinders

Each metering unit has its own tank, pipework, recirculation system, pressure gauge, and inlet to the head.

Fallplates and conveyor

The conveyor system is in three sections. Firstly there are 4 fallplates, each fully adjustable, fitted with individual motors, and controlled automatically from the console. Then a horizontal primary conveyor fitted with adjustable sidewalls along the entire length, and finally the secondary conveyor which is driven by the motor of the primary conveyor to achieve synchronization.

Ventilation Enclosure

The line is enclosed in sheet steel from the trough to the end of the slat conveyor and is ventilated by extraction fans. The conveyors between the end of the slat conveyor and the cut-off unit and further to the cure room are not enclosed.

Transfer Conveyor

Installed between cut off saw and final sloping take off conveyor. Foam blocks are taken to the cure room manually by means of a roller trolley

Block Cut-off

Horizontal cut-off knife, electronically synchronized to the main slat conveyor.

Cutting Unit

Consisting of the following:

1 Horizontal splitting machine
1 Vertical Band knife
1 Profiling machine
1 Contour cutting machine
1 Granulator

II PROJECT OBJECTIVE

The objective of this project is to eliminate the use of CFC-11 in the production of flexible slabstock foam.

The existing machinery for the production of flexible polyurethane slabstocks will be converted to operate using a process known as Carbon Dioxide. This process utilizes liquid carbon dioxide as an auxiliary blowing agent replacing CFC 11. Integral skin foam part production will be converted to operate with n-pentane. The HR production will be converted to "all water blown", thus allowing conversion without any replacing machinery.

III PROJECT DESCRIPTION

SCIMPOS is prepared to phase out ODS as soon as the new technologies have been acquired, the necessary machinery and equipment installed, and the technical staff trained.

-Through this project assistance will be provided in:

-Procurement of new equipment;

-Renovation of present equipment wherever technically and economically feasible;

-Installation, mechanical and electrical commissioning, chemical commissioning and training.

-The following package of equipment, instrumentation, and engineering services is required for the conversion process:

- Pressurized, certified storage system for Liquid Carbon Dioxide;
- Liquid Carbon Dioxide metering unit;
- Pre-mixing device for blending Liquid Carbon Dioxide;
- Multi-component mixing head designed to process LCD;

- Patented, adjustable foam laydown device, for optimum lay-down of reacting mixture over the slabstock conveyor;
- All relevant controls and connection to the existing plant;
- Modification of the existing machine to be adapted to the new laydown device as well as the additional control boards and pumps with piping;
- Modification of the existing conveyor.

3.1 SELECTION OF ALTERNATIVE EQUIPEMENT

Several selection of alternative technologies to replace CFC-11 could be considered as alternatives. Their advantages and disadvantages are detailed below.

The polyurethane flexible foam industry still uses several auxiliary blowing agents such as methylene chloride, HCFC-141b, HCFC-142b/HCFC-22 combinations and acetone. Whilst foams similar or even identical to those previously made using CFC-11 can be produced, the use of this group of blowing agents can only be for the short term as either they do not have a zero ODP or they contravene local or national emission standards.

Acetone also has the added problems of being extremely volatile (low flash point), and therefore presents a high risk of fire and explosion. Any machinery used in the conversion to acetone, including ventilation, will need extensive modification to be certified as explosion proof, and rigid safety procedures need to be enforced and followed.

Methylene chloride is also under environmental pressure for reasons of toxicity, and due to the fact that it is classified as a VOC (volatile organic compound) has restricted use in industrialized and developing countries including Cameroon.

Variable Pressure Foaming

This process involves the purchase of a completely new machine which is based on the principle of simulating the production of low density flexible foam at high altitude, as at high altitudes a blowing agent is not required to cool the foam. The process works by totally enclosing a full size production machine and in effect creating a reactor with a machine inside. The enclosure then provides a means of controlling temperature and pressure whilst the foam is being produced. The system was developed and patented by Recticel B.V. and Beamech UK and is subject to a license agreement for the equipment and technology. The main advantages of the process include: a reduced amount of ventilated gases to control, thereby reducing the size of scrubbing equipment required (mainly used in Europe and the USA); low density foams can be produced without blowing agents; densities as low as 8 kg/cu m can be produced thereby opening other interesting markets to the manufacturers.

Disadvantages of the process include: high cost of equipment; the process is very different to the way operators are used to working; the operator cannot see the foam while it is still in the machine; equipment maintenance and reliability need to be good in order to prevent the risk of a breakdown; an air lock is used to remove the cut block from the machine, this limits the size of the block to be produced, i.e. if the block is to be 60 m long, then the airlock needs to be 60 m long and hence power consumption is high.

Accelerated or Rapid Cure Systems

Most of the heat generated in the manufacture of a urethane foam is the result of the reaction between water and isocyanate. Normal practice limits the slabstock block exotherm to 165 °C, which with an all water blown foam limits the lowest foam density to circa 21 kg/m³. To produce lower density foams it was previously possible to increase the water level and keep with safe exotherm limits by the addition of an auxiliary blowing agent such as CFC-11. With this now being an unacceptable route the concept of "Accelerated or Rapid Cure" has developed.

The Accelerated Cure technology focuses on the total elimination of auxiliary blowing agents. It also provides the opportunity to remove undesirable emissions. The general concept of the process is the forced cooling of foam blocks thus allowing the production of low density water blown foams. If they were not cooled rapidly foams produced in this manner would self ignite. The exothermic heat is thus dispersed by drawing air through the block a relatively short time after production, nominally 10 minutes. The block temperature is thus reduced to a point where it is no longer critical.

The main advantages of the process are that: auxiliary blowing agents are eliminated, it is environmentally friendly - undesirable emissions are removed; foam hardness distribution is improved; cure time and hence foam storage time are reduced.

The disadvantages are mainly in the area of safety, although significant extra space will be needed to install the system for continuous processing. The safety aspect cannot be stressed too highly. Very accurate formulation control is needed and electrical / mechanical back up systems are necessary. Any failure in the system can potentially be disastrous. Blocks can generate excessive exotherm through a formulation defect or become trapped in the transport system resulting in the possibility of fire. It is therefore imperative that designed into any Accelerated Cooling process is a scheme which allows the rapid removal of hazardous blocks which is totally independent of the production process itself.

Accelerated Cure processes are also subject to a license agreement with either General Foam, USA or Crain Industries, USA.

Liquid Carbon Dioxide blowing technology (LCD)

From reference to published Patents, there appear to be 2 basic approaches to this technology. Both approaches use similar methods of storage, metering and addition of the LCD to the PU chemical mix. Main difference is in the froth laydown device.

Process A uses device called "gatebar" to drop the PU mix pressure to atmospheric. This pressure drop allows the froth to develop. Pressure is dropped by passing the mix through an elongated slot which extends over the greater part of the width of the foam machine conveyor. Typical slot thickness is quoted at about 200-300 microns.

Process B uses a device called "creamer" which is best described as a "filter pack" constructed of layers of perforated material through which the PU reaction mixture passes. The pressure drop is controlled by the number of layers and the size and number of perforations.

Advantages claimed for Process A:

* Ability to use a full range of different chemicals and additives, fillers, polymer polyols, pigment dispensers, because of the relatively large dimensions of the slot thickness compared with filler particles, etc.

* Very long production runs without build up of reaction products in the slot.

* Good consistency run-to-run.

* Even laydown of froth across conveyor. No need for top shaping device.

* Wide range of CO_2 levels from 1.5 to >10 pph (parts per 100 polyol)

Advantages claimed for Process B:

* Best cell structure with minimum pin-holing.

Successful results of LCD technology development and its full scale industrial application have confirmed that this technology is the most advance one to replace CFC-11 from environmental, technical and commercial points of view. The use of LCD as a blowing agent has many advantages including the following:

- possibility for manufacturing of foams of low density (15 kg/m^3 or even as low as 11 kg/m^3);

- local availability of liquid CO_2 (usually produced by air separation plants or by the CO_2 units at the soft drinks and beverages factories);

- CO_2 is environment friendly chemical material obtained from natural resources;

- no special industrial safety and health protection arrangements required;

- the technology proved its cost-effectiveness, technical and commercial advantages at more than 15 large scale industrial companies in different countries.

- better physical properties than CFC-11 or MC foams. Better compression set and resiliency.

Based on the above analysis of the available alternative to CFC-11 blowing agents and taking into consideration the respective national rules and regulations, the counterpart is requesting the technical assistance to replace CFC-11 by LCD in the manufacture of flexible PU slabstocks.

3.2 Impact on Production Process

There are four basic principles to the manufacture of foam by the CO_2 process:

1. The CO_2 must be kept liquid throughout the whole of the metering, blending and mixing processes until the mixed reactants are released to atmospheric pressure.

2. The liquid CO_2 is blended with one of the reactants - normally the polyol.

3. All reactants that meter directly to the mixing head must be fed at high pressure - greater than the equilibrium pressure for the mixture and CO_2.

4. The final pressure reduction and production of a froth must be very carefully controlled.

To implement these principles on practice at actual conditions of the counterpart, the following equipment and engineering services are required:

a. Liquid carbon dioxide storage equipment to ensure constant and accurate temperature and pressure monitoring.

b. In order to install a liquid carbon dioxide system at this plant the following modifications will be required: a platform for the liquid carbon dioxide system and a second mixing head will be suspended above the operator platform.

c. New high pressure polyol and TDI metering units are required; these are supplied as the LCD system. A carbon dioxide bulk store system is also required, and finally, a framework is required to carry the laydown device.

d. Carbon dioxide is a gas at normal temperature and atmospheric pressure; therefore, to prevent its gassing off on mixing with other foam ingredients, an LCD froth dispensing unit is required. This consists of a carbon dioxide metering unit, a pre-blend polyol metering unit, a high pressure mixing head and a laydown device.

e. Metering units for the individual activator streams need to be modified (pressure increase, diverter valves and recirculation) and split in order to feed the existing and the liquid carbon dioxide mixing head. Water addition needs to be modified to high-pressure dosing and recirculation.

f. The new controls for the metering units and the LCD frothing unit will be located close to the laydown device.

g. Ideally the materials used in the production of polyurethane foams (especially of low density) should be at a reasonably constant temperature, e.g. 20°C. This is particularly important for two main components, polyol and isocyanate.

h. Adjustment of existing new and modified equipment to the existing conveyor systems and ventilation is also needed.

I. Compressed air used for nucleation is normally at 6 bar and the CO_2 system operates at up to 20 bar. A cheaper and safer solution is the use nitrogen instead of the air.

j. Carbon dioxide has lower heat capacity than CFC-11 and less in used. This requires some of the water, usually in the formulation, to be replaced leading to lower foam hardness. To re-establish the hardness it is necessary to use crosslinkers or a co-polymer polyol, in a proportion of 5 to 20% of the current polyol. Also different surfactants are required.

k. SCIMPOS is producing mainly low density - hard foams, so reformulation of the different grades is needed and the benefits of a less expensive blowing agent will be partially offset by the higher costs of this co-polymer polyols and surfactants.

IV. INPUTS

4.1. Capital Goods Replacement

The equipment to be replaced or rebuilt as well as new equipment to be purchased is shown in Annex A.

4.2. Conversion/Training

Continuous flexible PU foam production. Within the framework of this project, technicians will be trained in (among others) the following areas:

- process and quality control in relation to the conversion;
- operation of the new machinery and equipment;
- maintenance of the new machinery and equipment;
- formulation using LCD technology for low density foams;
- safety regulations for using carbon dioxide and other chemicals used in the foam industry.

V. PROJECT IMPLEMENTATION

The project implementation will be carried out by, and according to the rules and procedures of UNIDO in close cooperation with SCIMPOS. To assist in and supervise the conversion process, to perform trouble-shooting and to provide assistance in product redesign work, specialized consultants will be provided by UNIDO.

A general Contractor, appointed by UNIDO for the implementation of the major project components (foaming system), will be responsible for supply of technology under licence and installation of equipment, commissioning of the converted line and on-the-job training of local staff. The detailed Terms of Reference for the services to be provided by the General Contractor as well as the final equipment specification and the work plan will be elaborated after project approval.

The permission from the local authorities for the introduction of the new technologies will have to be obtained by the respective company. They will also be responsible for the compliance of the new technologies with the established national standards.

SCIMPOS will be responsible for the following inputs:

- Provision of equipment (modified or new) required for the conversion process but not specified in the project budget.

- All activities and costs related to the civil construction and engineering work (including the provision of technical infrastructure) needed to accommodate the new technologies. (The relevant construction work will have to be arranged by SCIMPOS under the supervision of the General Contractor and in line with the established milestones for this project. The specification of work needed will be elaborated after project approval and necessary site inspection). These activities/costs are not reflected in the project budget.

- Technical staff as required by the Contractor.

- Provision of tools, transportation and lifting equipment as required.

- Local transportation, communication and secretarial facilities for the General Contractor and staff involved in the project implementation.

UNIDO, as Implementing Agency, has the necessary experience and capabilities to successfully implement the project at enterprise level. Upon approval of the project by the MFMP, the funds will be transferred to UNIDO. The respective project allotment document will then be issued by UNIDO's Finance Section. Any substantive or financial deviation from the approved project is subject to approval by the MFMP and UNIDO.

VI PROJECT COSTS

6.1 INCREMENTAL OPERATING COSTS

Liquid CO_2 is lower in price than CFC-11 and the quantity needed in the formulation to produce foams of equal density is reduced. These savings are however offset by the higher cost of additional chemicals, such as special polyols, surfactants and silicones to maintain the foam quality, the cost of operation and maintenance and the annual safety training required to educate personnel in the safe handling of liquid carbon dioxide.

The increase of the energy consumption to maintain CO_2 in liquid phase and operational costs to provide N_2 are to be taken into account.

A long "technology learning and formulations adaptation curve" is also considered. It will be dealing with yield losses during at least the first two-three years of operation. However, no funds are requested for tests and trials by the project.

The incremental operating cost is not considered in this project.

6.2 CONTINGENCY FUND

A contingency fund (10 percent of the total investment cost) was calculated. The fund is proposed to cover unforeseen expenses which might be incurred during the project implementation, e.g. purchase of small testing instruments which might be required during the conversion process, miscellaneous expenses, price escalation, etc.

6.3 TOTAL COSTS

Investment costs will cover capital investment costs (on CIF basis) for modification of existing manufacturing facilities, purchase of new machinery (see Annex A: "List of Equipment and Cost Estimates"), training, installation and consultancy services for modifications (see Annex B: "Project Budget").

- The incremental operating cost associated with this project is not considered.
- Implementing Agency's overhead costs are 13 percent.
- For the complete costs breakdown see Annex B: "Project Budget".
- For the calculation of the cost-effectiveness see Annex C: "Cost effectiveness"
- Requested funding by the MFMP: **US$ 733,370**

Annex A: LIST OF EQUIPMENT AND COST ESTIMATES

Item	Unit Cost $
1. Bulk store, transfer and metering equipment	
1.1 CO_2 bulk storage system, including CO_2 tank ($8m^3$), pipework and insulation	25,000
2. LCD system	
2.1 LCD system to be fitted to the existing machine, comprising:: * High pressure polyol blending unit * Liquid CO_2 Metering Unit, including flow metre * CO_2 Mixing head, complete with variable speed drive, lubrication system and pipework * Froth distribution system * Instrumentation and protection equipment * Commissioning and supervision of installation	350,000
2.2 High pressure polyol and TDI transfer systems and boost pump bypass, manual blocking valves, piping and insulation	5,000
2.3 High pressure TDI metering unit	55,000
2.4 High pressure water metering unit	10,000
2.5 CO_2 transfer and pressure control unit	45,000
2.6 Support frame to allocate LCD system	25,000
2.7 Licence agreement including technology transfer, computer programme of systems formulation	50,000
Total capital cost	**565,000**

Annex B: PROJECT BUDGET

Description	Duration Work months	Cost, US$
General consultancy services and training on LCD Technology		20,000
Engineering services		15,000
Miscellaneous: (contingency fund)	10%	58,500
Subtotal (investment costs)		649,000
Implementing Agency Overhead	13%	84,370
PROJECT TOTAL		**733,370**

Annex C: COST-EFFECTIVENESS

ODS consumption per year	kg	120,000
Total investment cost	US$	643,500
Cost-effectiveness	**US$/kg**	**5.40**

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P H A S I N G OUT CFC 11

Avril 1997

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S U M M A R Y

PROJECT COVER SHEET

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Counterpart Enterprise:	SONOPOL
Implementing Agency:	United Nations Industrial Development Organization (UNIDO)
Coordinating Ministry:	Ministry of Environment & Forestry, Cameroon

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This project will phase out 100 per cent of CFC-11 from the production of flexible slabstock foams used for the production of foam filled mattresses at **SONOPOL**. The chosen replacement alternative is Liquid Carbon Dioxide (LCD), a method of blowing low density foam utilizing Liquid Carbon Dioxide as a blowing agent. The project will be implemented through modification of existing production facilities and installation of supplementary safety equipment and instruments.

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Cameroon does not produce CFCs. According to the amended country programme the total consumption of CFCs in the production of polyurethane foam was about 500 MT in 1996. This figure reflects most probably only the import of pure CFC11 and does not consider that the majority of CFC 11 was imported to Cameroon already premixed inside the polyol compound of the polyurethane foam material; the actual CFC 11 consumption in Cameroon is much higher than the figures reflected in the first country programme. The demand of ODS at the moment is stagnant, but it is estimated that it will increase in the future again if the conversion will not be made.

Furthermore due to conversion plans of FAEM and U.C.E. to non CFCs, no CFC11 and 12 were imported for the 2 companies in 1996.

Cameroon plays an important role inside the Central African Customs and Economic Union (UDEAC) countries: Cameroon, Gabon, Congo, Central African Republic, Chad, Equat. Guinea; Cameroon exports a significant part of its production to these countries.

Moreover some of the flexible foam put on the local market for local consumption is exported indirectly through other commercial arrangements.

The sub-sector for flexible foams in Cameroon consists of 2 main manufacturers who are responsible for the ODS consumption of CFC-11 in the sector of flexible polyurethane manufacturing. The primary product produced, flexible polyurethane foam, is consumed in the local market with some export to the neighbouring countries. The product is mainly used in the production of soft furniture, upholstery, mattresses.

CFC-11 and CFC-12 have been the dominant ODS used in Cameroon. The CFC-11 is used as a blowing agent in the manufacturing of rigid insulation and flexible cushioning PU-foam.

Primary chemical companies importing polyurethane chemicals to Cameroon for the flexible foam market are: Enichem - Italy, Dow Chemicals - Belgium, Bayer Ag - Germany, Rhone-Poulenc - France, Arco Chemicals - France, Repsol - Spain.

1.2 Company's Background

The company SONOPOL (Société Nouvelle de Polyurethane) is an independant company established since 1972 in Cameroon. It is based in Douala in the industrial zone of BONABERI where it moved in 1977 in order to be connected to the national railway network. SONOPOL belongs to the private holding company Batoula with sister companies in the fields of plastics (SONOPAC), metallugical (METALCO) and glue (LITTORCOL). SONOPOL is involved in the production of flexible foam for use as mattress and upholstry industry. The other unit in charge of production of rigid polystyrene used in insulation is not considered in this project.

The company has 65 employees, 40 being assigned to technical tasks. The installed annual capacity of the plant is 3500 MT flexible slabstock PU-foam. Currently 1000 MT per annum is being produced. The production of foam of the last years reads as follows:

1992	1700 MT	1995	900 MT
1993	1500 MT	1996	1000 MT
1994	800 MT		

The company manufactures mainly flexible foam for the furniture and mattress industries.

Company established its production facility with the installation of a conventional, three paper (1 x bottom and 2 x sides) sloping conveyor type slabstock machine, purchased from Viking Engineering Ltd., UK. Maxfoam 270 slabstock foaming machine purchased from Beamech, UK.

At present SONOPOL annual CFC-11 consumption is as follows: 130 MT in the continuous slabstock production.

Since low density foam is and will be the important and growing part in the future, a blowing agent is required.
SONOPOL is prepared to phase out ODS as soon as the new technologies have been acquired, the necessary machinery and equipment installed and the technical staff trained.
Among the technological options currently available on a commercial basis and in line with the established policy of Cameroon to phase out the use of ODS, the company has chosen to replace CFC-11 by liquid carbon dioxide system in flexible PU-slabstock manufacturing.

Due to the relatively high CFC-11 consumption for the flexible foam manufacturing, SONOPOL decided to avoid the use of any transitional substance and to introduce carbon dioxide and n-pentane as an ultimate solution to meet the country's policy and strategy requirements related to the ODS phase out.

In order to ensure that no production is lost during the installation and commissioning of the new technology, it has been agreed that SONOPOL will continue using their existing mixing head, metering units, conveyor, paper systems, enclosure, ventilation and controls until the entire new system is installed.

Summary of Existing Equipment and Function

Maxfoam machine:

The Beamech (270) is a 270 kg/min, maxfoam type slabstock machine. This production method is quite different from the conventional sloping conveyor machines. The block shape produced is squarer and has a thinner bottom skin than the conventional one. Chemicals are metered to a fixed position mixing head either mounted above what is known as the fallplate section or inverted and mounted on the operator platform at the back of the machine. The mixed and reacting chemicals are delivered to a steel open topped container known as a trough, via flexible hoses. The trough is mounted on top of a beam carrying the first of the fallplates. The reacting foam fills up the trough from bottom to top and spills over into the bottom paper which is supported by the first of a series of fallplates. At this point, the side papers are introduced. The purpose of the fallplates is to try and mimic the rise profile of the foam in such a way that the use of gravity assists in the shaping of the top surface of the block. Therefore, as a general rule, the height of the trough is set at 70 % of the eventual block height. The reacting and expanding foam then flows downwards for 70 % of its rise and only expands vertically by 30 %. After the fallplates, the expanded foam passes onto a horizontal slat conveyor and the fallplate is enclosed by steel side walls. Typically the economics of the process are such that a saving of 6 % is obtained over the conventional machine producing domed blocks.

Storage facilities

Bulk storage area consisting of the following:

Polyol	1 x 180 MT uninsulated bulk storage tank Temperature conditioned drum storage area in the same location as the run tanks.
TDI	1 x 100 T uninsulated drum storage area.
CFC-11	Stored in drums with a total capcity of 5000 l.

Run Tanks

Consisting of the following:

Polyol	2x 11 MT all insulated and equipped with heating and cooling.
TDI	1x 7 MT, both insulated and equipped with heating and cooling.
CFC-11	1 x 1800 l
Additives:	A total of 8 MT in small drums

Paper Systems

A three paper system is used with a bottom paper turn up of between 10-15 mm. Two sides and one bottom paper rewind system is used. The three feeding supports have brake arrangements for keeping an even tension during foaming.

Mixing Head

The mixing headd is made by Beamech (UK) and consists of a fixed position inverted low pressure seven component mechanical mixing system with full recirculation. The inverted head is located on the operator platform and has two flexible hoses connected between it and the trough.

Total output: 270 kg/mn

Metering units

Consisting of 8 low pressure pumps equipped with manometers from 0 to 6 bars made by Bourdon (France):

The caracteristics of the various pumps are as follows:

- 1 Maag MNP 70/70 with the capacity of 155 kg/mn
- 1 Maag MNP 56/56 with the capacity of 150 kg/mn
- 1 Maag MNP 36/36 with the capacity of 60 kg/mn
- 3 Maag MNP 22/22 with the capacity of 50 kg/min
- 1 Maag MNP 45/45 with the capacity of 60 kg/min
- 1 Maag MNP 28/28 with the capacity of 55 kg/min

Each metering unit has its own tank, pipework, recirculation system, pressure gauge, and inlet to the head.

Fallplates and conveyor

The conveyor system is in three sections. Firstly there are 4 fallplates, individual length (6m) each fully adjustable, fitted with individual motors, and controlled automatically from the console. Then a horizontal primary conveyor fitted with adjustable sidewalls along the entire length, and finally the secondary conveyor which is driven by the motor of the primary conveyor to achieve synchronization. Capacity of the conveyor: 1000Kg - speed 6m/mn

Ventilation Enclosure

The line is enclosed in sheet steel from the trough to the end of the slat conveyor and is ventilated by extraction fans. The conveyors between the end of the slat conveyor and the cut-off unit and further to the cure room are not enclosed.

Transfer Conveyor

Installed between cut off saw and final sloping take off conveyor. Foam blocks are taken to the cure room manually by means of a roller trolley

Block Cut-off

Horizontal cut-off knife, electronically synchronized to the main slat conveyor.

Cutting Unit

Consisting of the following:
- 1 Carousel horizontal slitter.
- 1 Horizontal splitting machine
- 1 Vertical Band knife
- 1 Profiling machine
- 1 Contour cutting machine
- 1 Granulator

II. PROJECT OBJECTIVE

The objective of this project is to eliminate the use of CFC-11 in the production of flexible slabstock foam.

The existing machinery for the production of flexible polyurethane slabstocks will be converted to operate using a process known as Carbon Dioxide. This process utilizes liquid carbon dioxide as an auxiliary blowing agent replacing CFC 11. Integral skin foam part production will be converted to operate with n-pentane. The HR production will be converted to "all water blown", thus allowing conversion without any replacing machinery.

III. PROJECT DESCRIPTION

SONOPOL is prepared to phase out ODS as soon as the new technologies have been acquired, the necessary machinery and equipment installed, and the technical staff trained.

Through this project assistance will be provided in:

a) Procurement of new equipment;

b) Renovation of present equipment wherever technically and economically feasible;

c) Installation, mechanical and electrical commissioning, chemical commissioning and training.

The following package of equipment, instrumentation, and engineering services is required for the conversion process:

- Pressurized, certified storage system for Liquid Carbon Dioxide;
- Liquid Carbon Dioxide metering unit;
- Pre-mixing device for blending Liquid Carbon Dioxide;
- Multi-component mixing head designed to process LCD;
- Patented, adjustable foam laydown device, for optimum lay-down of reacting mixture over the slabstock conveyor;
- All relevant controls and connection to the existing plant;
- Modification of the existing machine to be adapted to the new laydown device as well as the additional control boards and pumps with piping;
- Modification of the existing conveyor.

3.1 SELECTION OF ALTERNATIVE TECHNOLOGIES

Several selection of alternative technologies to replace CFC-11 could be considered as alternatives. Their advantages and disadvantages are detailed below.

The polyurethane flexible foam industry still uses several auxiliary blowing agents such as methylene chloride, HCFC-141b, HCFC-142b/HCFC-22 combinations and acetone. Whilst foams similar or even identical to those previously made using CFC-11 can be produced, the use of this group of blowing agents can only be for the short term as either they do not have a zero ODP or they contravene local or national emission standards.

Acetone also has the added problems of being extremely volatile (low flash point), and therefore presents a high risk of fire and explosion. Any machinery used in the conversion to acetone, including ventilation, will need extensive modification to be certified as explosion proof, and rigid safety procedures need to be enforced and followed.

Methylene chloride is also under environmental pressure for reasons of toxicity, and due to the fact that it is classified as a VOC (volatile organic compound) has restricted use in industrialized and developing countries including Cameroon.

Variable Pressure Foaming

This process involves the purchase of a completely new machine which is based on the principle of simulating the production of low density flexible foam at high altitude, as at high altitudes a blowing agent is not required to cool the foam. The process works by totally enclosing a full size production machine and in effect creating a reactor with a machine inside. The enclosure then provides a means of controlling temperature and pressure whilst the foam is being produced. The system was developed and patented by Recticel B.V. and Beamech UK and is subject to a license agreement for the equipment and technology. The main advantages of the process include: a reduced amount of ventilated gases to control, thereby reducing the size of scrubbing equipment required (mainly used in Europe and the USA); low density foams can be produced without blowing agents; densities as low as 8 kg/m^3 can be produced thereby opening other interesting markets to the manufacturers.

Disadvantages of the process include: high cost of equipment; the process is very different to the way operators are used to working; the operator cannot see the foam while it is still in the machine; equipment maintenance and reliability need to be good in order to prevent the risk of a breakdown; an air lock is used to remove the cut block from the machine, this limits the size of the block to be produced, i.e. if the block is to be 60 m long, then the airlock needs to be 60 m long and hence power consumption is high.

Accelerated or Rapid Cure Systems

Most of the heat generated in the manufacture of a urethane foam is the result of the reaction between water and isocyanate. Normal practice limits the slabstock block exotherm to 165 °C, which with an all water blown foam limits the lowest foam density to circa 21 kg/m^3. To produce lower density foams it was previously possible to increase the water level and keep with safe exotherm limits by the addition of an auxiliary blowing agent such as CFC-11. With this now being an unacceptable route the concept of "Accelerated or Rapid Cure" has developed.

The Accelerated Cure technology focuses on the total elimination of auxiliary blowing agents. It also provides the opportunity to remove undesirable emissions. The general concept of the process is the forced cooling of foam blocks thus allowing the production of low density water blown foams. If they were not cooled rapidly foams produced in this manner would self ignite. The exothermic heat is thus dispersed by drawing air through the block a relatively short time after production, nominally 10 minutes. The block temperature is thus reduced to a point where it is no longer critical.

The main advantages of the process are that: auxiliary blowing agents are eliminated, it is environmentally friendly - undesirable emissions are removed; foam hardness distribution is improved; cure time and hence foam storage time are reduced.

The disadvantages are mainly in the area of safety, although significant extra space will be needed to install the system for continuous processing. The safety aspect cannot be stressed too highly. Very accurate formulation control is needed and electrical / mechanical back up systems are necessary. Any failure in the system can potentially be disastrous. Blocks can generate excessive exotherm through a formulation defect or become trapped in the transport system resulting in the possibility of fire. It is therefore imperative that designed into any Accelerated Cooling process is a scheme which allows the rapid removal of hazardous blocks which is totally independent of the production process itself.

Accelerated Cure processes are also subject to a license agreement with either General Foam, USA or Crain Industries, USA.

Liquid Carbon Dioxide blowing technology (LCD)

From reference to published Patents, there appear to be 2 basic apporaches to this technology. Both approaches use similar methods of storage, metering and addition of the LCD to the PU chemical mix. Main difference is in the froth laydown device.

Process A uses device called "gatebar" to drop the PU mix pressure to atmospheric. This pressure drop alows the froth to develop. Pressure is dropped by passing the mix through an elongated slot which extends over the greater part of the width of the foam machine conveyor. Typical slot thickness is quoted at about 200-300 microns.

Process B uses a device called "creamer" which is best described as a "filter pack" constructed of layers of perforated material through which the PU reaction mixture passes. The pressure drop is controlled by the number of layers and the size and number of perforations.

Advantages claimed for Process A:

* Ability to use a full range of different chemicals and additives, fillers, polymer polyols, pigment dispensers, because of the relatively large dimensions of the slot thickness compared with filler particles, etc.

* Very long production runs without build up of reaction products in the slot.

* Good consistency run-to-run.

* Even laydown of froth across conveyor. No need for top-shaping device.

* Wide range of CO_2 levels from 1.5 to >10 pph (parts per 100 polyol).

Advantages claimed for Process B:

* Best cell structure with minimum pin-holing.

Successful results of LCD technology development and its full scale industrial application have confirmed that this technology is the most advance one to replace CFC-11 from environmental, technical and commercial points of view. The use of LCD as a blowing agent has many advantages including the following:

- possibility for manufacturing of foams of low density (15 kg/m^3 or even as low as 11 kg/m^3);
- local availability of liquid CO_2 (usually produced by air separation plants or by the CO_2 units at the soft drinks and beverages factories);
- CO_2 is environment friendly chemical material obtained from natural resources;
- no special industrial safety and health protection arrangements required;
- the technology proved its cost-effectiveness, technical and commercial advantages at more than 15 large scale industrial companies in different countries.
- better physical properties than CFC-11 or MC foams. Better compression set and resiliency.

Based on the above analysis of the available alternative to CFC-11 blowing agents and taking into consideration the respective national rules and regulations, the counterpart is requesting the technical assistance to replace CFC-11 by LCD in the manufacture of flexible PU slabstocks.

3.2 Impact on Production Process

There are four basic principles to the manufacture of foam by the CO_2 process:

1. The CO_2 must be kept liquid throughout the whole of the metering, blending and mixing processes until the mixed reactants are released to atmospheric pressure.
2. The liquid CO_2 is blended with one of the reactants - normally the polyol.
3. All reactants that meter directly to the mixing head must be fed at high pressure - greater than the equilibrium pressure for the mixture and CO_2.
4. The final pressure reduction and production of a froth must be very carefully controlled.

To implement these principles on practice at actual conditions of the counterpart, the following equipment and engineering services are required:

a. Liquid carbon dioxide storage equipment to ensure constant and accurate temperature and pressure monitoring.

b. In order to install a liquid carbon dioxide system at this plant the following modifications will be required: a platform for the liquid carbon dioxide system and a second mixing head will be suspended above the operator platform.

c. New high pressure polyol and TDI metering units are required; these are supplied as the LCD system. A carbon dioxide bulk store system is also required, and finally, a framework is required to carry the laydown device.

d. Carbon dioxide is a gas at normal temperature and atmospheric pressure; therefore, to prevent its gassing off on mixing with other foam ingredients, an LCD froth dispensing unit is required. This consists of a carbon dioxide metering unit, a pre-blend polyol metering unit, a high pressure mixing head and a laydown device.

e. Metering units for the individual activator streams need to be modified (pressure increase, diverter valves and recirculation) and split in order to feed the existing and the liquid carbon dioxide mixing head. Water addition needs to be modified to high-pressure dosing and recirculation.

f. The new controls for the metering units and the LCD frothing unit will be located close to the laydown device.

g. Ideally the materials used in the production of polyurethane foams (especially of low density) should be at a reasonably constant temperature, e.g. 20°C. This is particulary important for two main components, polyol and isocyanate.

h. Adjustment of existing new and modified equipment to the existing conveyor systems and ventilation is also needed.

i. Compressed air used for nucleation is normally at 6 bar and the CO_2 system operates at up to 20 bar. A cheaper and safer solution is the use nitrogen instead of the air.

j. Carbon dioxide has lower heat capacity than CFC-11 and less in used. This requires some of the water, usually in the formulation, to be replaced leading to lower foam hardness. To re-establish the hardness it is necessary to use crosslinkers or a co-polymer polyol, in a proportion of 5 to 20% of the current polyol. Also different surfactants are required.

k. SONOPOL is producing mainly low density - hard foams, so reformulation of the different grades is needed and the benefits of a less expensive blowing agent will be partially offset by the higher costs of this co-polymer polyols and surfactants.

IV INPUTS

4.1. Capital Goods Replacement

The equipment to be replaced or rebuilt as well as new equipment to be purchased is shown in Annex A.

4.2. Conversion/Training

Continuous flexible PU foam production

Within the framework of this project, technicians will be trained in (among others) the following areas:

- process and quality control in relation to the conversion;
- operation of the new machinery and equipment;
- maintenance of the new machinery and equipment;
- formulation using LCD technology for low density foams;
- safety regulations for using carbon dioxide and other chemicals used in the foam industry.

V PROJECT IMPLEMENTATION

The project implementation will be carried out by, and according to the rules and procedures of UNIDO in close cooperation with SONOPOL. To assist in and supervise the conversion process, to perform trouble-shooting and to provide assistance in product redesign work, specialized consultants will be provided by UNIDO.

A general Contractor, appointed by UNIDO for the implementation of the major project components (foaming system), will be responsible for supply of technology under licence and installation of equipment, commissioning of the converted line and on-the-job training of local staff. The detailed Terms of Reference for the services to be provided by the General Contractor as well as the final equipment specification and the work plan will be elaborated after project approval.

The permission from the local authorities for the introduction of the new technologies will have to be obtained by the respective company. They will also be responsible for the compliance of the new technologies with the established national standards.

SONOPOL will be responsible for the following inputs:

- Provision of equipment (modified or new) required for the conversion process but not specified in the project budget.
- All activities and costs related to the civil construction and engineering work (including the provision of technical infrastructure) needed to accommodate the new technologies. (The relevant construction work will have to be arranged by SONOPOL under the supervision of the General Contractor and in line with the established milestones for this project. The specification of work needed will be elaborated after project approval and necessary site inspection). These activities/costs are not reflected in the project budget.
- Technical staff as required by the Contractor.
- Provision of tools, transportation and lifting equipment as required.
- Local transportation, communication and secretarial facilities for the General Contractor and staff involved in the project implementation.

UNIDO, as Implementing Agency, has the necessary experience and capabilities to successfully implement the project at enterprise level. Upon approval of the project by the MFMP, the funds will be transferred to UNIDO. The respective project allotment document will then be issued by UNIDO's Finance Section. Any substantive or financial deviation from the approved project is subject to approval by the MFMP and UNIDO.

VI. PROJECT COSTS

6.1 INCREMENTAL OPERATING COSTS

Liquid CO_2 is lower in price than CFC-11 and the quantity needed in the formulation to produce foams of equal density is reduced. These savings are however offset by the higher cost of additional chemicals, such as special polyols, surfactants and silicones to maintain the foam quality, the cost of operation and maintenance and the annual safety training required to educate personnel in the safe handling of liquid carbon dioxide.

The increase of the energy consumption to maintain CO_2 in liquid phase and operational costs to provide N_2 are to be taken into account.

A long "technology learning and formulations adaptation curve" is also considered. It will be dealing with yield losses during at least the first two-three years of operation. However, no funds are requested for tests and trials by the project.

The incremental operating cost is not considered in this project.

6.2 CONTINGENCY FUND

A contingency fund (10 percent of the total investment cost) was calculated. The fund is proposed to cover unforeseen expenses which might be incurred during the project implementation, e.g. purchase of small testing instruments which might be required during the conversion process, miscellaneous expenses, price escalation, etc.

6.3 TOTAL COSTS

Investment costs will cover capital investment costs (on CIF basis) for modification of existing manufacturing facilities, purchase of new machinery (see Annex A: "List of Equipment and Cost Estimates"), training, installation and consultancy services for modifications (see Annex B: "Project Budget").

- The incremental operating cost associated with this project is not considered.
- Implementing Agency's overhead costs are 13 percent.
- For the complete costs breakdown see Annex B: "Project Budget".
- For the calculation of the cost-effectiveness see Annex C: "Cost effectiveness"
- Requested funding by the MFMP: **US$ 733,370**

Annex A: LIST OF EQUIPMENT AND COST ESTIMATES

Item	Unit Cost $
1. Bulk store, transfer and metering equipment	
1.1 CO_2 bulk storage system, including CO_2 tank ($8m^3$), pipework and insulation	25,000
2. LCD system	
2.1 LCD system to be fitted to the existing machine, comprising:: * High pressure polyol blending unit * Liquid CO_2 Metering Unit, including flow metre * CO_2 Mixing head, complete with variable speed drive, lubrication system and pipework * Froth distribution system * Instrumentation and protection equipment * Commissioning and supervision of installation	350,000
2.2 High pressure polyol and TDI transfer systems and boost pump bypass, manual blocking valves, piping and insulation	5,000
2.3 High pressure TDI metering unit	55,000
2.4 High pressure water metering unit	10,000
2.5 CO_2 transfer and pressure control unit	45,000
2.6 Support frame to allocate LCD system	25,000
2.7 Licence agreement including technology transfer, computer programme of system formulation	50,000
Total capital cost	**565,000**

Annex B: PROJECT BUDGET

Description		Cost, US$
General consultancy services and training on LCD Technology		10,000
Engineering services for adaptation of existing foaming machine to the LCD system		10,000
Miscellaneous: (contingency fund)	10%	59,000
Subtotal (investment costs)		649,000
Implementing Agency Overhead	13%	84,370
PROJECT TOTAL		**733,370**

Annex C: COST-EFFECTIVENESS

ODS consumption per year	kg	130,000
Total investment cost	US$	643,500
Cost-effectiveness	**US$/kg**	**4.99**