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Ozone-friendly industrial development

# Impact and lessons learned—plastic foams

UNIDO in the Montreal Protocol—
technology transfer to developing countries

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All tons are metric and all dollars are U.S. dollars.

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## About this series

This booklet is one of a series of six designed for specialists interested in the effectiveness and efficiency of UNIDO's sectoral programmes for phasing out the use of ozone depleting substances (ODSs) by industry and agriculture. Covering refrigeration and alternative technologies for domestic appliances, refrigerant management plans, plastics foams, solvents (including process agents and aerosols) and fumigants, they focus on the complex interventions required to replace technologies, equipment and operating procedures in the main ODS-consuming sectors. Each sector calls for a different set of technical, economic and (in some cases) social solutions. Case study presentations show that the common benefit of adopting of ozone-friendly technologies is the opportunity to improve productivity, product design and quality and to move into new markets. The series documents not only the implementation of cost-effective projects, but also the many indirect benefits of UNIDO's work—such as technology transfer, employment generation, support for SMEs and institutional capacity building.

The series places UNIDO's efforts as an implementing agency for the Multilateral Fund (MLF) of the Montreal Protocol in the context of UNIDO's mission to support developing countries and countries in transition in their pursuit of sustainable industrial development. UNIDO interprets such development as the accomplishment of three things: (i) protecting the environment—with industry complying with environmental norms, efficiently utilizing non-renewable resources and conserving renewable resources; (ii) encouraging a competitive economy—with industry producing for export as well as domestic markets; and (iii) creating productive employment—with industry promoting long-term employment and increased prosperity.

**Abbreviations**

| | |
|---|---|
| CFC | chlorofluorocarbon |
| FYROM | Former Yugoslav Republic of Macedonia (FYR Macedonia) |
| HCFC | hydrochlorofluorocarbon |
| LCD | liquid carbon dioxide |
| MLF | Multilateral Fund of the Montreal Protocol |
| ODS | ozone-depleting substance |
| ODP | ozone-depleting potential |
| PE | polyethylene |
| PS | polystyrene |
| PU | polyurethane |
| R & D | research and development |
| SME | small or medium scale enterprise |

# Contents

FOREWORD

The year 2002 has seen a milestone in UNIDO''s contribution to preserving the stratospheric umbrella that protects life on earth from the sun's radiation - the ozone layer. Eleven years ago in October, the Organization became an implementing agency to the Montreal Protocol. It accepted, thereby, the challenge of helping cut back the use of ozone depleting substances (ODSs) that threaten the future of all life forms on our planet.

In that short interval since UNIDO became an implementing agency for the Montreal Protocol's Multilateral Fund, the Organization successfully eliminated an annual consumption of more than 24,500 tons of industrial chemicals that would otherwise have torn an even larger hole in the protective ozone shield. The allocation of 25 per cent of the Multilateral Fund's resources to UNIDO, increasing, as of 2003, thanks to the strong portfolio of projects, is unequivocal recognition of the Organization's track record in tackling the industrial challenges of today's world.

Working closely with the Fund's Secretariat and the United Nations Environment Programme, UNIDO applies its expertise in industry to transferring technology and know-how so that ODS consumption and its ozone depleting potential are reduced. Their impact has far exceeded the limited staff resources available within the Organization. A major success factor has been the establishment of an organizational branch dedicated to Montreal Protocol activities, which I created when transforming UNIDO in 1998.

Since then, UNIDO's role in combating ozone depletion has gone from strength to strength. But it has also taken on a new dimension, namely to help developing countries to benefit from globalization through increased trade. By enabling their industries to comply with environmental export requirements, UNIDO has opened up new markets for their industrial goods thus encouraging the growth of selected manufacturing sectors. The cooperation between UNIDO, the Multilateral Fund, other international agencies, donors and ODS technology recipients in pursuing the goals of the Montreal Protocol, demonstrates that collective multilateral efforts can indeed have a substantial impact on threats - environmental, economic and others - that face mankind.

Meanwhile the task of eliminating ODSs from industry is far from finished. To meet the challenges ahead, UNIDO is expanding its support for Montreal Protocol activities. In addition to individual projects to transfer ozone-friendly technologies, UNIDO will help developing countries plan their own phase-out programmes for ODSs. This summary booklet and its accompanying technical reports are an insight into one of the key value-added services that UNIDO offers its clients. They are also an industrial blueprint for protecting the ozone layer in the twenty-first century.

Carlos Magariños
Director-General

## Plastic foams

Expanded plastic foams—flexible, rigid, semi-rigid, moulded or integral skin polyurethane-based foams as well as extruded polystyrene and polyethylene foams—are produced by incorporating and fixing small gas bubbles in a liquid or melted polymer compound. The commonly used blowing agents for the polyurethane foams are CFC-11, methylene chloride and water; polystyrene and polyethylene extruded foams use CFC-12, HCFC-22 or their mixtures. The cost, profitability and required structure and performance parameters of the final products (density, softness or hardness, thermal insulation value etc.) are achieved by varying the technological parameters (e.g. composition and nature of chemical components and the temperature, time and pressure of the reacting system etc.)

*Rigid polyurethane (PU) foams*
Rigid PU foams are used for thermal insulation in domestic and commercial refrigerators, on-the-spot insulation and production of sandwich panels for industrial and civil construction. They are also used to insulate heat transfer pipelines and storage tanks in food processing and pharmaceutical industries. The conventional technology relies on CFC-11 as the blowing agent. The main quality requirements are foam density (usually in the range of 30-60 kg/cu m), thermal insulation value (K-value), structural hardness and compliance with relevant safety standards.

*Flexible PU foams*
Flexible PU foams are widely used in furniture, textiles (upholstery) and automotive industries as well as for packaging. Conventional production technology employs water and CFC-11 as blowing agents. In many developing countries, small enterprises use methyl chloride which is toxic and, therefore increasingly banned under national regulations. Density (usually in the range of 15-25 $kg/m^3$), softness or hardness (depending upon market requirements) and pinhole index (size and number of larger bubbles) are the main parameters.

*Semi-flexible and integral skin PU foams*
Semi-flexible and integral skin PU foams are used to produce automotive dashboards, door components and other vehicle parts. They are also used for various elements for furniture industry and in shoe production. The current technology is based on combination of water and carbon dioxide ($CO_2$) and CFC-11 blowing processes. Reflecting the specific applications, foam densities range from 30-350 $kg/m^3$. One of the most important market requirements with the integral skin foams is the quality of outer surface of the final products.

*Extruded polyethylene (PE) and polystyrene (PS) foams*
PS and PE foams are used for packaging of food and other goods, for insulation in construction and food storage industries and for pipeline and other insulation. Conventional extrusion technology to produce them is based on CFC-12 and HCFC-22/CFC-12 blowing agents.

***UNIDO in the plastic foams sector***

UNIDO addressed the issue of CFC-free polyurethane foam development already in 1986-1990 with the technical assistance project setting up the Polyurethane Institute at the Chemical Complex SODASO in Tuzla in former Yugoslavia. The project trained a core group of 12 national scientists and technicians at the Institute of Polymers, Detroit, U.S.A. It provided laboratory and testing equipment to enable the new institute to elaborate alternative chemical components and formulations of CFC-free polyurethane foams.

The first UNIDO project to phase-out CFC-12 removed 196 tons from the production of extruded polystyrene insulation boards at AdveChem, Egypt. Approved at the 10th meeting of the MLF Executive Committee in June 1993, it provided an alternative blowing technology based on a mixture of HCFC-22/HCFC-142b—replacing an HCFC-22/CFC-12 blowing system. Subsequent UNIDO projects in the plastic foam investment portfolio are shown in table 1.

**Table 1 UNIDO plastic foam investment projects***

| | Africa | Asia and Pacific | Europe | Latin America and Caribbean | Total | Sectoral share awarded to UNIDO (%) |
|---|---|---|---|---|---|---|
| Number of projects per region | 21 | 57 | 18 | 28 | 124 | 27.4 |
| ODS to be phased out by UNIDO (tons) | 1,175 | 9,054 | 1,347 | 1,281 | 12,857 | 36.3 |
| Funding approved by UNIDO ($ millions) | 5.23 | 45.29 | 6.1 | 6.86 | 63.5 | 24.7 |
| | | | | | UNIDO share in MLF foam sector | % |
| Total ODS to be phased out from foam sector under the MLF | | | | | 58,238 | 22.2 |
| Total MLF funding approved for foam sector ($ millions) | | | | | 328.7 | 19.9 |

*Approvals up to April 2003.
Source: Report of the 39th MLF Executive Committee on Alternative Plastic Blowing Technologies.

*Alternative plastic blowing technologies*

Both the project beneficiaries in the plastic foam sector and the implementing agencies face challenges when selecting an alternative non-ozone depleting blowing technology.

(1) There are now a number of alternative chemical substances and systems available to replace ODS in various sub-sectors of plastic foam manufacturing. None, however, are equivalent to the chemicals currently used in terms of thermal, physical and chemical properties, blowing or other performance parameters and costs. In many instances, replacing ODS with alternative chemicals also calls for changes to foam formulations and the use of chemical components compatible with the new blowing agent. As a result each alternative technology needs to be developed, transferred and adapted in order to maintain the required quality, standardization and performance parameters of final products at reasonable production cost.

(2) The extremely wide variety of plastic foam products for different applications usually requires a learning period to adjust to the alternative blowing technology for each final product, and to achieve stable quality parameters under reasonable production costs. Moreover, some alternative technologies require extreme safety precautions for storage, raw materials handling and during the production process.

(3) In most cases a significant part of the production equipment and support systems needs to be replaced or significantly modified in order to meet all technological and industrial safety regulations. This requires capital investment for which, in accordance with established financial criteria of the Multilateral Fund, only the incremental capital cost is eligible for funding. This means that end-users are financially responsible for the difference between the actual conversion cost and the incremental capital cost project budget.

(4) In the cases where the market price of an alternative blowing agent (e.g. butane, n-pentane, $CO_2$) is lower than that of the currently used CFC-11 and CFC-12 compounds, the possible savings over a period established by the MLF have to be calculated and deducted from the estimated incremental capital cost budget. In such cases (bearing in mind the rules for incremental capital cost budgets), the financial capability of end-users is crucial.

(5) Most producers of expanded plastic foams are SMEs, i.e. with modest technical and management skills and limited financial capabilities. Converting them to the advanced ozone-friendly technologies faces a corresponding list of difficulties. Usually, they are addressed through umbrella projects covering a number of small individual enterprises. A particular difficulty is for project beneficiaries and UNIDO project managers to jointly select the most appropriate alternative technology – taking into account all the technical and commercial requirements.

The choice of non-ozone depleting alternative technologies is from a list recommended by the Technology Options Committee of the Multilateral Fund as being eligible for funding for the plastic foam sector:

1. Rigid polyurethane foams
   - Hydrocarbons (pentanes, butane)
   - HCFC-141b
   - Water (for limited application of foams)

2. Flexible polyurethane foams
    - Liquid $CO_2$ (LCD technology)
    - Hydrocarbons (pentanes)
    - HCFC-141b

3. Extruded polyethylene and polystyrene foams
    - Atmospheric gases and their blends
    - Hydrocarbons, including LPG
    - HCFCs
    - HFCs
    - $CO_2$/butane blends.

Taking into consideration the significant investments in the production equipment and safety systems required for the application of hydrocarbons as blowing agents, SMEs currently select the more easily adapted HCFC-141b technology. However, with an ODP of 0.11 (compared to 1.0 for CFCs), HCFC-141b is not an ultimate solution. Since HCFC-141b will also be banned from use, at some point in the future companies that convert to HCFC-141b will be obliged to apply zero-ODP technology. Leading petrochemicals producers are thus developing new zero-ODP chemicals to replace HCFC-141b.

*Technology promotion and transfer*

UNIDO has provided technical assistance to developing countries in the polymer processing and plastics transformation industry for many years—helping set up 12 technical assistance and R & D plastics and polymers centres in different regions. UNIDO project managers were already well prepared, technologically and managerially, to provide assistance and services for the complete execution cycle of the plastic foam related projects under the Montreal Protocol.

In particular, UNIDO took the lead in promoting liquid carbon dioxide (LCD) blowing technology as the most advanced alternative solution for flexible PU foam. Patent owners cooperated with UNIDO experts to promote its acceptance as an eligible alternative, elaborating a guidance document that includes a section on licensing the technology as part of an investment project. As a result, UNIDO's share of LCD projects in the foam sector of the Multilateral Fund represents 32 per cent in terms of ODP, 28 per cent in terms of number of LCD projects and 31 per cent in terms of funding.

Given the challenges outlined above and in order to ensure sustainability and competitiveness, each individual or umbrella project in expanded plastic foams features a technical assistance package that includes:

- Transfer of a selected blowing technology (including a licence agreement in cases when the technology is protected by patent);
- Transfer of technology know-how as an integral part of equipment procurement and engineering services;
- Transfer of expertise and experience through consultancy services and training of personnel;
- Technology adaptation and maturity during commissioning and trial tests;

- Quality control of final products against the respective standard requirements;
- Production and market cost analysis of converted processes and products.

To ensure sustainability and competitiveness of converted SME foam producers' operations, UNIDO developed a new implementation concept for industrial rationalization within groups of enterprises that are included in the umbrella projects. Covering measures required for technical, commercial and management optimization of the conversion process, the concept emphasizes:

- Reducing the total number of enterprises within the cluster through selective closures and relocation of production lines to the technically and financially stronger and better managed enterprises, concurrently maintaining the previous total production capacity of the cluster;
- Reducing the total number of enterprises and/or the total number of production lines through closure of selected enterprises to optimize and balance the production capacity of the individual factories. Remaining enterprises are thus enlarged through relocation of production lines from the factories to be closed.

Both concepts are applied in the strategy to phase-out CFC-12 from the extruded foams sub-sector in China, where five umbrella projects will eliminate 3,930 ODP tons from 108 enterprises at a total programme cost of $19.7 million. The programme is under joint execution by UNIDO and China's State Environment Protection Administration (SEPA).

Implementing these industrial rationalization concepts leads, however, to additional conversion costs that were not foreseen in the existing financial rules of the Multilateral Fund, namely:

- Reimbursement or compensation of the owners (shareholders) of the enterprises;
- Compensation for the operational and managerial personnel;
- Retraining of the personnel for new jobs.

Practical implementation of the concepts (especially the procedure for closing enterprises) also has to be in accordance with the local environmental regulatory system and legislation. This in turn should include not only environmental restrictions, but also measures governing financial and social compensation and assistance from the government to motivate the public and private sectors to introduce advanced environmentally friendly technologies.

***Secondary technology transfer***

Converting existing plastic foam lines and units not only concerns substitution of blowing agents. It also requires a package of technical assistance and services consisting of the following:

- Techno-commercial analysis and selection of an alternative technology;
- Specification of new equipment, support systems and engineering services to be provided to replace existing machinery when justified by the selected technology;
- Specification of equipment, components, spare parts and engineering services to be provided for modification and retrofitting of existing machinery when replacement is not required;

- Procurement of equipment and services, supervision of project sites preparation, commissioning and test trials;
- Technology/know-how transfer and adaptation;
- Quality and safety certification;
- Training of operational and managerial personnel.

Given that the average age of existing production equipment is in the range of 10-15 years, conversion is an opportunity to provide the enterprise with a new generation of production lines, units, instrumentation and support systems along with the latest technologies and skills. Thus, at the end of the day, all project beneficiaries receive new or substantially modernized equipment, new technology and trained staff. It is their opportunity to increase their production capacity, maintain the quality of their products and ensure sustainability.

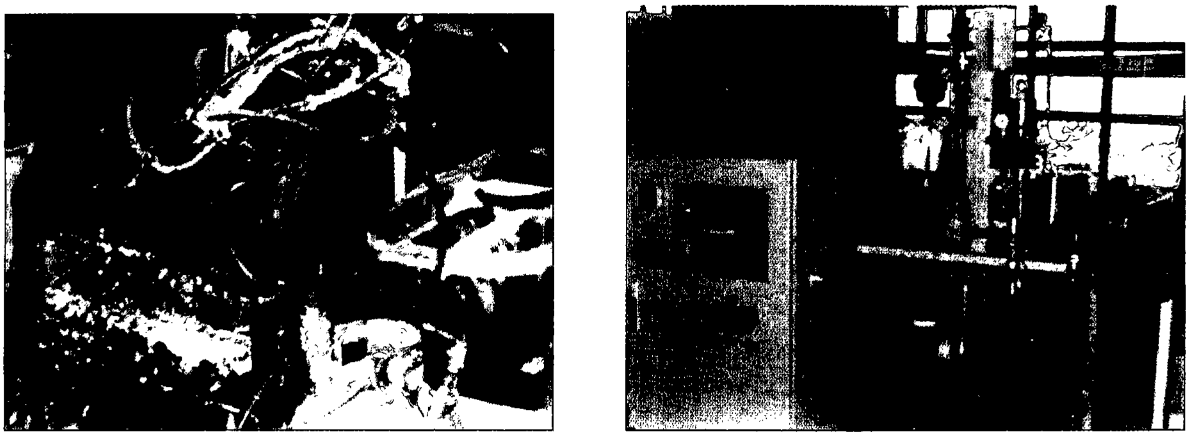

Fig. 1: Foaming machine before and after conversion, Frinko Refrigeration Plant, The FYR of Macedonia

*CASE STUDIES*

*Phasing out ODS from extruded polyethylene foam packaging materials in China*

Sector: Extruded polyethylene (PE) foams
Company: Included in three umbrella projects, P. R. China
Project title: Phase-out of ozone depleting substances (ODS) from manufacturing of PE foamed extruded pack
aging foams.

***Background***

Contributing to a plan to phase-out ODS from polyethylene and polystyrene extruded foam, three umbrella projects are designed to convert CFC-12-based technology to an ozone-friendly one at more than 80 very small enterprises that manufacture packaging for agricultural products at rural locations in different provinces.

UNIDO and the State Environment Protection Administration of China (SEPA) elaborated a Strategy Plan based on the new joint UNIDO/SEPA programme implementation modalities to address this large group of SMEs.

The total cost of the projects, which aim to eliminate 2,800 tons of CFC-12, is approximately $14 million. The project budgets foresee project beneficiaries co-financing the conversion process to the extent of 10-20 per cent of the overall conversion cost.

***Alternative technology selection***

All the companies covered by the projects opted to use butane to replace CFC-12 in the conversion. Their reasons:

- Proven technology in processing and product performance
- Environmental acceptability
- Acceptable toxicity
- Adaptability to the existing equipment
- Cost-effectiveness
- Availability in the recipient country in large quantities.

They also recognized the main drawback of butane: its high flammability, requiring very stringent safety precautions.

***Services provided***

In order to achieve the project objectives and to ensure future export capabilities, competitiveness and sustainability of the sub-sector, the following measures were implemented:

- Relocating the new or retrofitted production facilities and concentrating them in only 15 selected and modernized factories—in accordance with the national strategy of "industrial rationalization of SME sub-sectors";
- Designing the new production technology so that it fully meets ISO 14000 standard requirements, so that there will be no obstacles for export of the agricultural products being packaged;
- Better technical, safety and financial capabilities as well as market stability for the enlarged factories;

- Minimizing the possible social impact of the rationalization concept through government-managed compensation and retraining of staff, assistance in further employment.

Relevant know-how on new formulations of chemicals as well as on processing parameters is provided by the suppliers of the chemical components for the alternative liquid butane blowing technology, and through the consultants' services. Learning time—required for each converted factory for the technology adaptation and maturity under assistance of local consultants—is allowed for.

Because of the explosive nature and flammability of butane, relevant safety precautions are also foreseen by the project, including safety certification of converted enterprises and training of operational personnel.

***Impact***

- 2,800 tons of ODP are being eliminated;
- Production facilities fully meet ISO14000 requirements for packaging of agricultural products;
- Latest technology transferred and adapted;
- The sub-sector is rationalized according to China's national policy on SME sectors' development;
- Consulting services and chemical component suppliers provide know-how on chemical formulations and processing parameters for using liquid butane blowing technology;
- Local consultants assist each converted factory during the learning period required to adapt the technology and bring it to maturity;
- Safety precautions foreseen by the project include safety certification of converted enterprises and training of operating personnel.

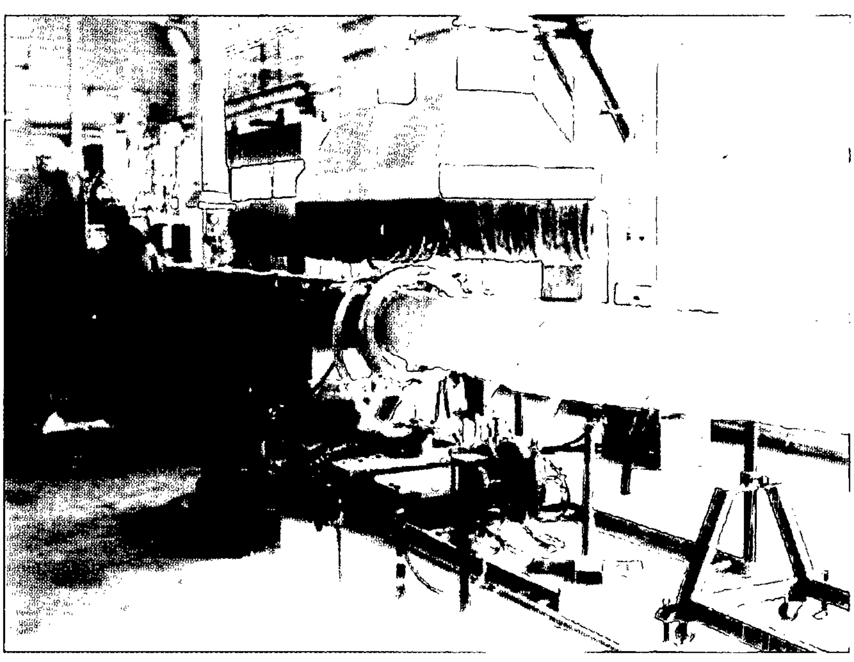

Fig. 2: Butane blowing technology powers Chinese expanded polyethylene extrusion line

## *Liquid carbon dioxide blowing technology for flexible PU slabstock: 18 projects in 6 countries*

Sector: Flexible PU slabstock foams
Company: 18 projects in 6 countries (Algeria, Cameroon, Iran, Tunisia, Turkey, Syria)
Project title: Alternative liquid carbon dioxide (LCD) blowing technology for manufacturing of flexible PU slabstock foams

### *Background*

Production of flexible slabstock foams is based on continuous/discontinuous process with a possibility of changing the quality (grade) of foams on the fly, i.e. without interruption of the line operation. The companies use 30-90 tons of CFC-11 annually. The density of foams is in the range of 15-22 kg/cu m.

### *Alternative technology selection*

Because market requirements are very sensitive to the quality parameters of this type of foam, owners and managers of the enterprises are very knowledgeable and careful when selecting alternative technologies. From the various alternatives, they opted for liquid carbon dioxide blowing (LCD) technology as an immediate environmentally friendly solution, rather than other approaches that were *ad interim* solutions. The process does not require special industrial safety and health protection arrangements and the LCD technology offered the possibility of a low-density foam (less then 15 kg/cu m) production. LCD is also available locally and the process is thus cost effective. The technology is considered the most advanced alternative technology to replace CFC-11 from environmental, technical and commercial standpoints.

Developed and patented by Hennecke (Germany), Cannon Viking (U.K.) and Beamech (U.K.), it is also one of the most advanced ozone-friendly technologies available. Although all three technologies are based on liquid $CO_2$ blowing agent, the engineering design of the relevant equipment is different.

Currently, UNIDO is implementing 18 LCD technology projects (in Algeria, Cameroon, Iran, Tunisia, Turkey and Syria) for a total cost of $8.8 million.

### *Services provided*

The projects provide the following technical assistance for conversion:

- Assistance to end-users in selecting the most appropriate alternative technology bearing in mind requirements of quality standards and performance parameters of the products.
- Preparation of terms of reference for sub-contracting of technology and services.
- Selection of suppliers of the technology, equipment and engineering services based on international competitive bidding.
- Assistance to the end-user in preparing licence agreements with selected suppliers indicating all quality and standard requirements and legal obligations of both parties.
- Installation and commissioning of equipment and trial tests according to an agreed programme.

- Training of operational and managerial personnel at the premises of the selected supplier followed by on-the-job training.
- Quality control and independent comprehensive tests of the final products against the conditions stipulated in the licence agreement and requirements of respective standards.
- Production costs assessment and new products market analysis in order to optimize the new production programme.

*Impact*

- 1,740 tons of ODS eliminated
- Quality of foam improved substantially to industrial standards and requirements
- New markets opened for soft- and low density foam
- Latest technology introduced
- Production capacity increased by 15 to 20 per cent
- Production process improved
- Staff trained

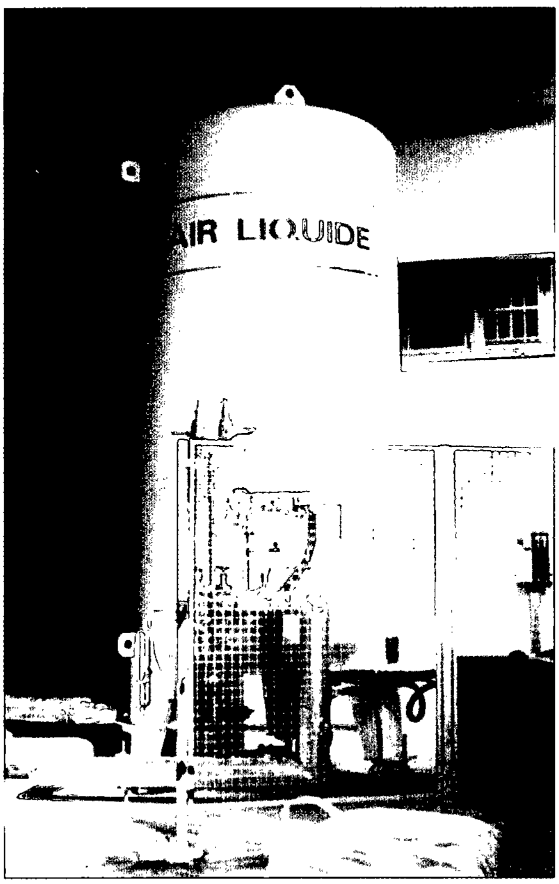


Fig. 3: Africa's first liquid carbon dioxide-based polyurethane slabstock line at Sud Inter Mousse (Tunisia) features patented laydown unit and liquid $CO_2$ storage (insets)

## *Other project examples*

*Alternative n-butane blowing technology in manufacturing of extruded PS foams*
For fast-food packaging in Argentina and Venezuela, five projects replaced CFC-12 with n-butane as the blowing agent. In accordance with guidance of the Multilateral Fund, the existing extrusion lines were retrofitted and the relevant n-pentane storage system and safety instrumentation provided.

Using the new equipment and advanced technology, project end-users were able to increase their production capacities, improve quality of CFC-free products and through that strengthen and stabilize their market positions. Based on the production cost analysis and reviews of market demand, the production programmes of the converted plants were adjusted accordingly.

*Substitution of CFC-11 by n-pentane in production of sandwich panels*
Making components for pre-fabricated houses in Iran, the company Rashestan is one of the region's major producers and suppliers of earthquake-proof prefabricated houses (including refugee camps) to be erected in the desert.

In the framework of the $600,000 project, and in accordance with the technical requirements of the alternative blowing technology, the end-user was provided with the relevant foaming equipment, storage transfer and dosing n-pentane stream as well as with safety related systems and instrumentation.

Because the PU sandwich panels are for construction, it was crucial to develop new formulations of the chemical components of the rigid PU foams in order to achieve the relevant parameters of the construction codes and the standards in terms of flammability of the final products. For these purposes, the know-how for formulations of chemical components for different thickness of panels was developed in cooperation with the chemicals and foaming equipment suppliers as well as with assistance of local experts. It was necessary, for example, to use a flame retardant and a higher amount of polyol and isocyanine for n-pentane blowing, and which increased in the cost of the final products. Production cost was therefore thoroughly analysed to optimize the cost and quality of products.

*Replacement of CFC-11 by HCFC-141b in SME's production of rigid PU sandwich panels*
In comparison to the large or medium size producers of PU sandwich panels for construction and refrigeration industries, small-scale enterprises are not able to apply the most advanced pentane based blowing technology for several reasons:

- Due to their small CFC-11 consumption, the funding provided by the Multilateral Fund is small;
- Because of high overall investment costs in converting to pentane-based technology, the level of cost-sharing (co-investment) by the SME end users will be very high;
- Because of high production cost and relatively small production capacity, profits will also be low, with a long time period for a reasonable return on investment;
- It will not be possible to ensure safe operation of plants in accordance with safety standard requirements.

In view of the above, the HCFC-141b alternative blowing technology is widely used by the Article 5 countries. Taking into account the higher price of HCFC-141b (some 10-15 per cent higher compared to CFC-11) the production cost and market price of panels using HCFC-141b will also be higher. New production programmes of the converted SME enterprises were therefore analysed to optimize the cost and quality of final products.

Fig. 4: Centralized supply ensures preblended HCFC-141b -based chemicals for the converted SMEs in China.

*Production of PU integral skin components using HCFC-141b blowing technology*
Integral skin polyurethane components for the automotive industry (dashboards, door components, armrest, headrest etc.) are among the most demanding group of PU products. Substituting CFC-11 at Sector Co. and Frisocar (Brazil) could thus affect quality and standard requirements, competitiveness in the markets, traditional business relations between the car assembling plants and suppliers of various components, environmental legislation of ISO 14000 and related export/import restriction etc.

Although n-pentane and HCFC-141b blowing technologies were considered the most appropriate, in practice the technology requires top-level expertise and experience of production equipment modification or replacement. It calls for substantial changes of processing technological parameters and, most importantly, development or transfer of know-how for new HCFC-141b or n-pentane based formulations of chemical components.

The formulations and processing parameters depend on the volume, shape and particular application of the final products. Therefore, the know-how needs to be developed for each individual product—a long process that needs to be jointly overcome by the suppliers of chemical materials and production equipment, operational staff of the end-users with participation of local or international consultants. On-the-job training of the operational personnel is another key element of the conversion process.

Substituting HCFC-141b for CFC-11 also leads to increases in production costs. Therefore, the modified production programme of Sector Co. and Frisocar had to be reviewed and analysed from the point of view of production costs, quality and performance parameters of the products and market demands.

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