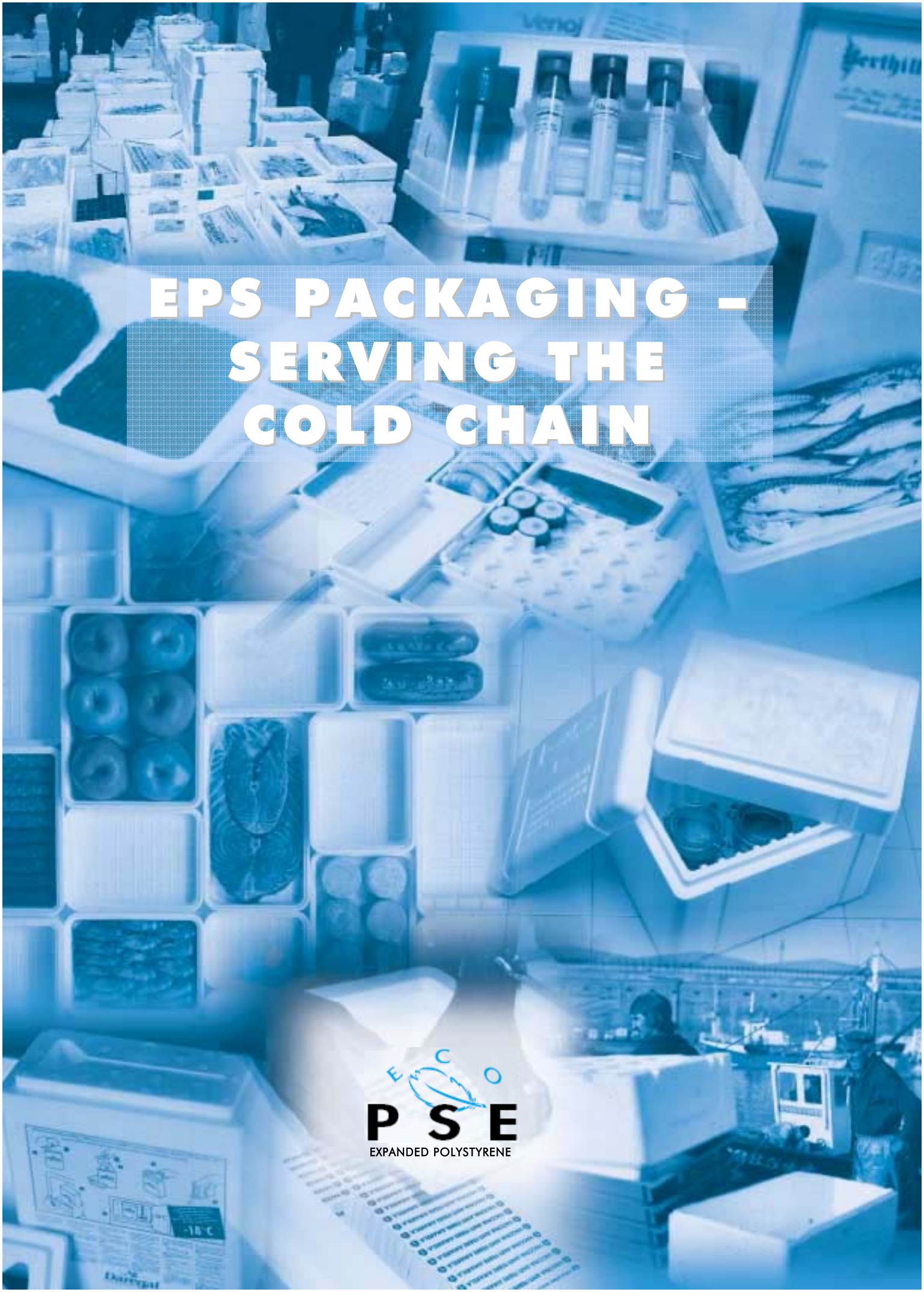

EPS PACKAGING – SERVING THE COLD CHAIN

ECO PSE
EXPANDED POLYSTYRENE

CONTENTS

ECO PSE in brief

- **Structure**: GIE (Groupement d'intérêt Economique – Economic Interest Group)
- **Created:** 1993
- **Missions**: Support interest in used EPS packaging. Information on the properties of EPS packaging.
- **Founding members**: CORSTYRENE – ISOBOX TECHNOLOGIES /SERAIC - KNAUF - NOVEMPOR – SICAL – SIPA/PLASTYROBEL.
- **Participating members**: SIPASEN, SPMP, VANPLAST.
- **Representation**: 95% of the French market for moulded EPS packaging.

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Isothermal, Hygienic and Mechanical EPS: 3 forms of protection in one.

Published around eight months ago, an editorial entitled "Working to strengthen the Partnership" opened a case compiled with players from the packaging chain of white/brown goods based, amongst other things, on the compatibility between the reduction in the source of packaging and the preservation of its mechanical protection features. The case in favour of more protection put forward by the leader in specialist distribution rested on a unanimously shared view: warehouses and end users are increasingly further apart.
As we were compiling this new case, we realised that opinions gathered from cold chain specialists led to similar conclusions: new food channels increase distances between foodstuffs and consumers. This shared prerequisite, corollary of increasing globalisation, makes it easier to understand why functional analysis performed on food packaging dispatched to supermarkets now gives the same weight to isothermal if not hygienic protection as to mechanical protection. So there we have it. Distributors are starting to follow the example of health and drugs specialists, cold chain (and hygiene) pioneers who, long ago, chose EPS packaging.
The pioneering event "semaine du froid" (Cold week) which a distributor has scheduled for his clients for the beginning of the summer should pave the way for real materials partnerships dedicated to "serving the cold chain".
This is what EPS packaging manufacturers, ECO PSE members, want to demonstrate by publishing this new case, as well as through the launch of their new advertising campaign. So take a look at the fourth cover page !

Serge GALAUP
General Secretary

EPS: MULTIFACETED MARKETS

Protection and hygiene are undoubtedly EPS's well known main features. However, its excellent isothermal properties also help to boost its market shares in areas where logistics chain constraints make it a necessity: in 1999, 45% of EPS packaging used nationally was used to maintain packaged products at the right temperature. In key markets – such as meat and fish products – as well as in many niche markets, the resolutely modern and dynamic EPS easily accommodates the constraints of all the different sectors.

Present throughout the world, EPS consumption continues to grow, especially in Asia, the world leader with a 38% market share. Western Europe follows with a 28% share, while the USA is in third place with 21% of the market (sources CMAI, Houston).
The building and packaging industries, represent the biggest shares of the EPS market, with relative world shares of 50% and 40% respectively. The one exception is North-East Asia where packaging leads the way with 57% compared to 35% for the building industry.

EPS Packaging in France: 20% growth over 3 years

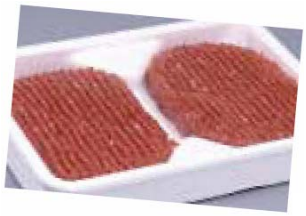
Apart from South-East Asia and Eastern Europe, two figure growth can be expected between now and 2004: +49% in Northern Asia, mostly from China, +15% for the USA and +16% for Europe. This is no surprise in the light of previous years: while European consumption figures rose from 178,000 tonnes in 1997 to nearly 200,000 tonnes in 1999, France's consumption figures rose by +20% over the same period.
Out of 37,000 tonnes used in 1999, the use of EPS packaging alone for cold chain applications reached 16,000 tonnes, that is to say 45% of all EPS packaging

BACKGROUND

produced in France. But the food industry is not the only sector involved, with 450 tonnes of EPS used annually, the health and pharmacy sector often uses the cold chain to transplant organs, vaccines and biological samples. These are not the only strategic niches, as the food industry itself is also characterised by strong segmentation in which EPS's adaptability and insulating properties provide a huge variety of specific solutions.

An insulating packaging with multiple uses

Seafood products – 7,000 tonnes of EPS for fish containers – remain a major food industry sector, in which EPS dominates thanks to three fundamental roles which it fulfils simultaneously: insulating protection, hygienic protection and anti-shock protection. Three major advantages which also make it the main material for meat and poultry packaging, a sector which uses no less than 5,000 tonnes of EPS per year. It should be noted that EPS has continually evolved in response to the segment's requirements: different colours for added value positioning, crush resistance, thermal and gas



insulation to prolong meat's shelf life, aeration systems to reduce exudation, or absorbent bases to trap moisture.

There are other sectors, too, in which EPS has become synonymous with added value, particularly with products which are very sensitive to changes in temperature. There are many examples: from sea food aesthetically presented on a fresh EPS platter or even conserved in modified atmosphere EPS containers, to the packaging of luxury ice-creams or keeping very delicate fruit at the required temperature or even protecting aromatic herbs in EPS boxes, expanded polystyrene provides a simple and ingenious solution thanks to the combination of its two intrinsic properties – its insulation properties and its resistance to shocks.

While transport remains the stumbling block in the cold chain, EPS packaging proves to be an efficient solution against micro-ruptures. These inevitably happen with the repeated opening and closing of refrigerated lorries during home deliveries, a service which is developing with the increase in e-commerce.

Other reasons for micro-ruptures in the cold chain include the loading and unloading from one storage area to another, or even transportation in a non-refrigerated vehicle as a result of "Cash and Carry" buying by catering professionals. These micro-ruptures can be managed thanks to insulating containers, such as EPS boxes, or mixed solutions combining EPS and refrigerating compounds (carbonic ice or eutectic plates) which meet the requirements of "e-commerce". These markets will doubtless provide good development opportunities: indeed, while many marketed food products are very delicate, geographical distances between products and consumers are growing, justifying the growing severity of regulations, to which EPS responds by consolidating its presence in areas where hygiene and low temperatures are prerequisites.

MANAGING MICRO-RUPTURES IN THE COLD CHAIN

E-commerce is undeniably on the up: Galeries Lafayette, Casino and Carrefour-Promodès had already launched their own sites with links to fresh and frozen foods. Since the summer of 2000, Auchan and Picard have followed suit…

With e-commerce, home delivery is bound to develop, especially for fresh and frozen foods which suit the needs of urban surfers who have little time to cook…The need to maintain low temperatures is therefore a challenge for all these retailers. Tri-temperature vehicles for Telemarket.fr deliveries (Galeries Lafayette) or bi-temperature for Ooshop's deliveries, Picard's elder brother, part of the Carrefour-Promodès group - these modes of transport do have their disadvantages, however. Not only can generators break down, but the loss of insulation during the delivery phase is a real possibility: the exchange surface with the outside is indeed significant when doors are frequently opened.

That is why some distributors have given up on refrigerated lorries: Cmescourses.fr (Casino) prefers to use insulated containers and refrigerants, as well as insulated boxes to insulate foods and carbo-ice inside containers, while Leclerc Cannes delivers its products in insulated enclosures fitted with eutectic plates. E-commerce for foodstuffs opens up an exciting market for insulating materials such as EPS.

Apart from the home delivery sector, the catering sector – schools, retirement homes, holiday camps, hotels and restaurants – is also exposed to the consequences of breaking the cold chain; as is the transport of chemical and pharmaceutical products. Here again, the problem can be solved with simple and efficient solutions: combining adequate transport with insulated packaging has thus become, for all sectors, the most reliable means of managing the cold chain.

LOGISTICS

THE CHALLENGING LOGISTICS OF PRESERVING LOW TEMPERATURES

Even though recent outbreaks of listeriosis could not be traced back to the quality of food products or to any anomaly in the logistics chain, logistics chain professionals – producers, logistics specialists and distributors - are on tenterhooks. The chain is now more than ever at the heart of concern expressed by the 'Direction Générale de l'Alimentation' in France, as well as the European Commission, whose intentions could result in a massive shake-up.

After leaving its place of production and before arriving on the consumer's plate, a fresh food product goes through many stages and is handled by many different players…

Each link in the chain is aware of its imperfections, the most time-critical stages in the process being loading and unloading operations which recur on average three times: during the transfer of the finished product from production lines to storage facilities, from storage facilities to logistic centre and finally from there to point of sale. All in all, and if all goes according to plan, the process will last seven or eight hours, during which time products will be subjected to temperature changes.

This is only an average to which should be added: the unloading times at points of sale, the time elapsed during transfer from storage facilities to the store's shelves, and the time the product spends in the shopper's trolley before finally making it to the latter's refrigerator…

EPS AND COLD STORAGE ROOMS

Insulating material *par excellence* and particularly efficient even at the lowest temperatures down to –150°C, EPS is often fitted to cold storage rooms.

Typically, the EPS material used to manufacture the panels fitted to cold storage rooms is sandwiched between two cell walls like self-supporting Isowall for example. Manufactured by Miret-Mitzeler, insulating panels and hangar building units specialist, it has an EPS insulating web. Compatible with all structures whether metal or concrete, this type of panel is also used to renovate existing installations as many traditional cold storage rooms, food installations and other refrigerated facilities are still built to old standards. "They need extensive renovation work to be brought up to the requirements of new sanitary regulations in terms of ease of cleaning of surfaces, for example" explains Olivier Gadaix, Marketing executive for the Gadard group, the leading manufacturer of sandwich panel insulation products in France.

"That is why we offer a wide range of products to suit different budgets and requirements, like the RT insulating panel which is one of the cheapest. Their faces (steel plate, polyester, etc.) are bonded to an expanded polystyrene web of a specific weight of between 16 and 19kg/m^3 for insulating purposes. This type of panel has been used to bring all sorts of facilities up to new standards: bakeries, professional kitchens, cold storage rooms in ice cream factories, cosmetics factories, butchers, delicatessen shops, meat storage, pharmaceutical industry facilities…"

EPS undoubtedly benefits from the significant increase in the use of light materials by the building industry. But as Miret explains, EPS's technological advances have made it a key material in terms of insulation: it keeps its initial thermal resistance indefinitely thanks to an excellent thermal conductivity co-efficient with a lambda of 0.035 W/m°K. Although light, it has high resistance to compression. Water resistant – its extreme impermeability shows no capillarity – it is also rotproof: neither fungi, parasites, nor bacteria can attack it. It is therefore unalterable and resists ageing. Moreover, improvements in panels ensure their integrity: the Isowall system seals for the Miret panels, for example, absorb all dilation and contraction movement, so that there is no thermal bridge and no interior or exterior condensation. An integrity which contributes to EPS's well known stability.

It is well know that, particularly during hot periods, food can be exposed to several unexpected rises in temperature, thus reducing the reliability of its use-by date.

The packaging's insulating properties prove an important additional benefit in limiting the consequences of this during these brief ruptures in the cold chain (c.f. boxed text 'Managing micro-ruptures in the cold chain' page 3).

Other parameters of uncertainty also come into play, such as the reliability of refrigeration equipment, as well as storage areas, transport vehicles and refrigerated cupboards at the point of sale. Many installations require updating in order to meet regulations.

It is also here that the reliability of insulating materials, such as EPS, which makes up the cold storage room panels, is essential (see previous page 'EPS and cold storage rooms')

But how can the performance of this equipment be evaluated? Cemagref has already been looking into this issue for some time, concentrating on two areas: "A group is studying heat flow and transfer during refrigerating procedures", explains Jacques Guilpart, head of Cemagref's Refrigerating Procedures Engineering research unit.

"Researchers are studying the thermal behaviour of food, studying cold from the point of view of the foodstuff, our objective being to find ways of increasing the amount of time it can be kept while preserving quality.

A second group is studying the thermal dynamics of refrigerating installations (refrigerator or cold storage room), the objective being to produce cold efficiently and respect the environment at the same time."
In order to help companies working in the cold chain to diagnose and evaluate their installations' performances, Cemagref, Transfrigoroute France and Perifem* decided to create the Economic Interest Group 'GIE Cemafroid'.

"One of our main objectives is to strengthen expertise in the cold chain among the large distribution networks, says Bernard Commère, Executive Director of the GIE. The major players have made the cold chain a priority, and wish to carry out studies on fragile products such as fish** or the fourth range. We can follow the temperature of food across the cold chain, for example, by placing a sensor inside packaging in order to measure the effect of temperature on the foodstuff along the entire cold chain." This lies, in effect, at the heart of the matter .....

*Cemagref: Research Institute for agricultural and environmental engineering; Transfrigoroute and Perifem: inter-professional technical associations, one for directed temperature transport and the other for commerce and distribution.

** See page 10 "Cold's biology: the case of the sardine"

TRANSPORT AND THE COLD CHAIN: WHAT DO THE REGULATIONS SAY?

The most recent decree of 20th July 1998 setting out *"the technical and hygienic conditions applicable to the transport of food"* updated the 1974 decree by reinforcing the ATP agreement (An agreement relating to the international transport of perishable foodstuffs), by enlarging its field of application to cover all foods destined for human consumption, and by emphasising the responsibility of the professionals concerned.

Categorised under the decree, as raw food products, foods stable at ambient temperature and microbiologically sensitive foods, the products present, in terms of obligations, a grading in relation to the category to which they belong.

FROZEN GOODS	–18°C
FISH PRODUCTS AND LIVE SHELLFISH	0 to +2°C (Melting ice)
MINCED MEATS	0 to +2°C
PREPARED MEATS, POULTRY, SMALL GAME	0 to +4°C
VACUUM PACKED DELICATESSEN PRODUCTS	0 to +3°C
4th RANGE VEGETABLES (PACKED SALADS READY TO USE)	+1 to +4°C

There are additional specific requirements for the transportation of sensitive foods, particularly those which require a directed and controlled temperature – for example, the obligation of recording air temperatures during the transportation of frozen goods and minced meats.

Even if the recent European regulation reform project (c.f. page 6) in no way changes these rules, it does, nevertheless, envisage having these standards "confirmed" by a scientific committee. Moreover, its "Transport" chapter presents six articles which aim to eliminate all contamination between foodstuffs, by recommending the separation of products, as well as the use of specialised receptacles in vehicles and/or containers marked indelibly with the words "For foodstuffs only." The chapter also mentions "efficient cleaning between two loadings", and concludes that vehicle and/or container receptacles must be designed so that temperature levels can be monitored."

WATCH THIS SPACE

EUROPEAN REGULATION BASED ON RESPONSIBILITY

"The most radical shake-up in hygiene rules relating to food safety over the last 25 years ….." This is how the European Council's Commission for health and consumer protection describes the new project which abrogates the EEC/93/43 general directive and 16 other directives …

While the EEC/93/43 general directive covered food hygiene *"for all stages of preparation, transformation, manufacturing, packaging, storage, transportation, distribution, handling and sale or handover to the consumer"* the new regulation project – no longer known as a directive – intends to hit even further upstream, as well as downstream, as implied by the expression *"from farm to table"*.

An expression which encapsulates the first principle of the change: the regulations are to be applied to all foodstuffs and to all food chain operators, including those involved in primary production, such as farming and fishing businesses.

The second principle, the HACCP (Hazard Analysis Critical Control Point) self-monitoring and risk management method, which up until now was highly recommended so that each professional should be able to prove that he/she has fully respected the hygiene rules, will be *"obligatory for all companies producing non-primary foodstuffs."* Primary producers must in turn apply good practice codes.
The third principle, *"the traceability of all foodstuffs and all the ingredients used to make them"* will also be obligatory and will have as a consequence: registration numbers allowing products to be followed, the keeping of registers identifying ingredient and foodstuff suppliers, and recall procedures for products presenting a risk …..
Special mechanisms will be put in place in order to facilitate the implementation of the HACCP system in small and medium sized companies. For foodstuffs of animal origin, meat based transformed products, fishery and dairy products, additional specific hygiene rules are also planned, and new measures scheduled to reduce contamination between carcasses during slaughter. The obligations of the member States veterinary authorities will have to be specified: an important initiative by the Commission which aims to amend food checks is planned in the white paper for the end of the year 2000. Zoo-sanitary measures which up until now have been spread over 7 different directives will be amended and updated.

Globally the new project aims to simplify and harmonise *"the detailed and complex recommendations which were previously scattered over 17 directives"*, and which will thus be *" simpler to apply*. Each company will be clearly responsible for the safety of its foodstuffs, while having greater freedom and flexibility in terms of how it chooses to achieve this on its premises." *Another innovation should be noted: the aforementioned "proposals"* will take *"the form of Council and Parliament regulations, and not directives, in order to ensure a uniform application and greater transparency, and to facilitate a rapid updating in line with new technical and scientific advances."*

To be continued …

EPS AND ENERGY RECOVERY - THE RUNGIS MODEL

The 'Marché d'Intérêt National' (M.I.N) at Rungis remains to this day the largest fresh produce market in the world in terms of surface area (232 hectares), supplying 18 million Europeans, of which 12 million are French. It is a site made up of 5 sectors: flowers, fruit and vegetables, dairy products, meat products, and the fisheries section, whose 19,000m^2 covered area, the largest of all, sees 300 tonnes of seafood products pass through every day from Tuesday to Saturday.

"As EPS is the essential element in seafood packaging, we recover 600 to 700 tonnes per year, which is equivalent to the EPS tonnage used by the port of Boulogne," says Laurent Dumargne, Environment Manager for Semmaris, the company responsible for managing the market. "A tonnage which should in time almost double with the restructuring of the whole of the fisheries sector from 2001 onwards, which will optimise the collection of used containers on the one hand, and on the other, make new EPS containers available to wholesalers and retailers in a special storage zone," explains Claude Taussac, Manager of the fisheries sector. Currently the seafood containers recovered at Rungis are reconverted on site into a precious combustion supplement for the M.I.N incineration site. Only 6 or 7 seafood containers are needed to produce the same caloric power as one litre of fuel. This highly calorific end for cold chain packaging simply links it to its origins, EPS being basically derived from oil. What is more, this initial saving, highly beneficial during this period of expensive crude oil, also directly contributes to the urban heating system used not only at Rungis' M.I.N, but also at the hotel park, the traffic centre, Orly airport and the 120 hectares of the SENIA industrial park, thanks to the M.I.N incineration plant's energy recovery system.

However, "the projected growth of recovered EPS allows for the planning of a dedicated recycling subsidiary," adds Laurent Dumargne. In effect, if recycling is generally reserved for clean packaging from industrial sources, the scale of the source announced by Semmaris could mean that, for the first time in France, the conditions necessary for an economically viable recycling subsidiary for soiled packaging will be met. Watch this space…

Why chose insulating packaging ?

Highly insulating packaging is necessary when:

Contents are alterable and there is no guarantee of stability at room temperature. Any increase in temperature would be detrimental to their quality. They must therefore be kept at temperatures below room temperature all the way through the logistics chain, from producer to consumer. This applies to fresh meat and fish, ice creams…

The contents must be protected from thermal shock (in other words, it must be protected from sudden temperature changes which might occur in its surroundings) in transit and storage. This applies to some pharmaceutical products, fresh fruit and vegetables, some types of wine, some seafood and live crustaceans…

The contents must be kept at temperatures above room temperature all the way through the logistics chain, from producer to consumer. This applies to some ready prepared meals delivered hot where the temperature must not fall below 63°C (in compliance with the decree of 20/07/98 relating to *"Technical and hygiene requirements for the transport of edible products"*).

Why is EPS packaging the number one choice for food industry and health professionals ?

Only a packaging material with low thermal conductivity can satisfy the strict requirements imposed by regulations as well as quality and safety criteria, with which food industry and health professionals must comply as regards the stability of the temperature of their products

A material's thermal conductivity is characterised by the value of its thermal conductivity coefficient (λ). It indicates its permeability to the passing heat flow (the heat flow decreases or increases the temperature of the package's contents) within a given thermal gradient (ie. the temperature difference between packaged content and its surroundings).

Typically, a packaging material's insulating property is characterized by the opposite of its thermal conductivity (1/λ). The higher the value of 1/λ, the more efficient the packaging is in terms of its insulating property.

Figure 1 shows that EPS's insulating property is very high compared to conventional packaging materials, confirming that EPS is ideal for producing packaging where thermal insulation is a requirement.

EPS's insulating property is therefore used to ensure that a product is kept at even temperature below or above that of its surroundings for as long is necessary or to protect it from sudden temperature changes and postpone the balancing out of room and contents temperatures (figure 2).

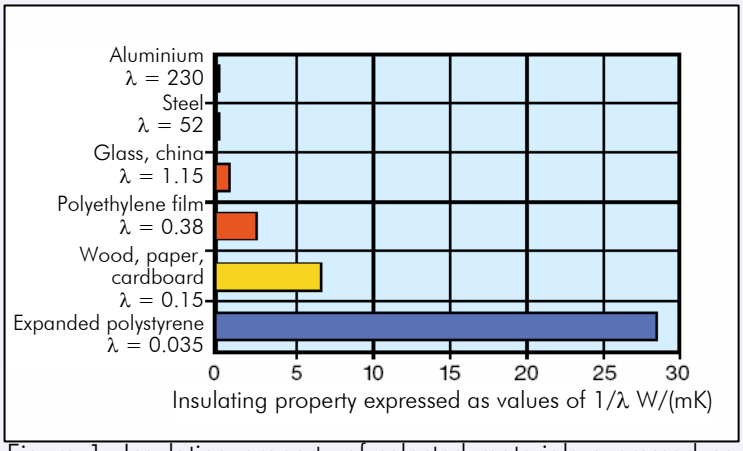


Figure 1: Insulating property of selected materials expressed as the opposite of their thermal conductivity coefficient 1/λ W/(mK)

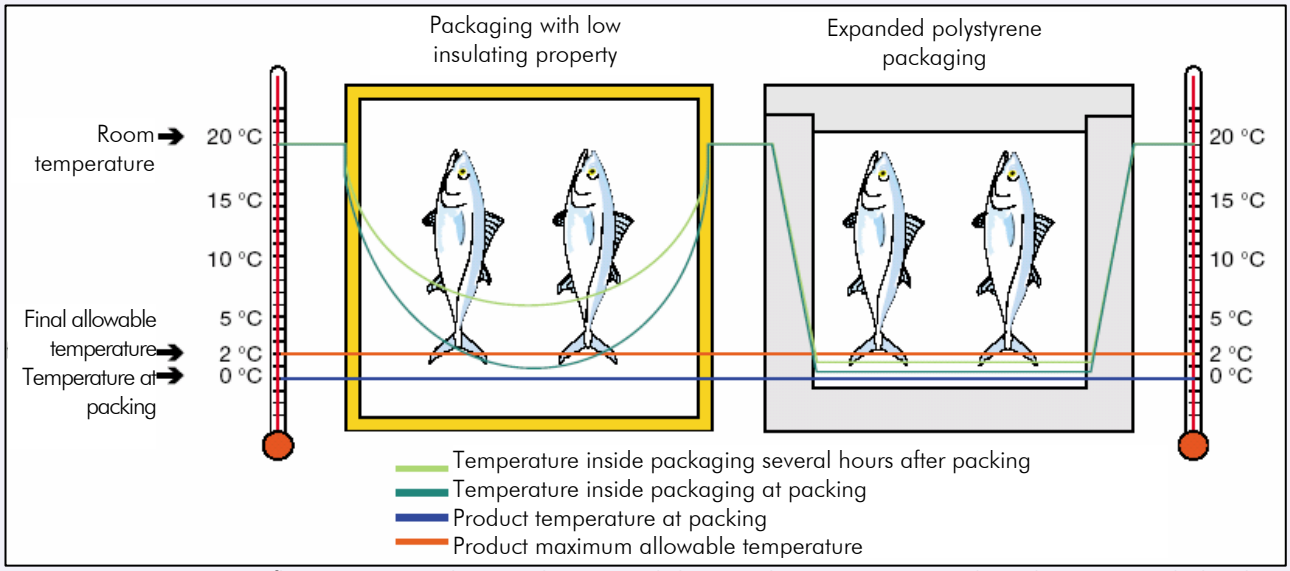


Figure 2 : Temperature fluctuations inside a packaging with low insulating property and inside an expanded polystyrene packaging. EPS packaging effectively postpones the balancing out of room and content temperatures, maintaining all parts of the product at an even temperature inside its packaging.

What is the minimum thickness of EPS packaging without cooling element?

When transport and storage conditions are known, the EPS packaging characteristics needed to guarantee that the food product will not suffer as a result of thermal environment variations can be determined.

In cases where thermal gradient between the contents of the package and its surroundings decreases (in other words where the product's temperature moves towards that of its surroundings if a cooling element is not placed inside the packaging with the product), the duration of thermal insulation which separates the moment at which the temperature of the product is θ_0 from the moment at which the temperature of the product is θ_1 can be calculated with the following formula.

Calculation of EPS packaging thickness – WITHOUT cooling element –

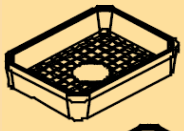
$$\Delta t = m_p \cdot c_p \cdot \left(\frac{1}{\alpha} + \frac{e}{\lambda} \cdot \frac{S \cdot 3{,}6}{\ln \frac{\theta_e - \theta_0}{\theta_e - \theta_1}} \right)$$

$$\text{so, } e = \lambda \left(\frac{\Delta t \cdot S \cdot 3{,}6}{m_p \cdot c_p \cdot \ln \frac{\theta_e - \theta_0}{\theta_e - \theta_1}} - \frac{1}{\alpha} \right)$$

Δt = thermal insulation duration between θ_0 and θ_1 – hours
m_P = packaged product weight – kg
c_P = packaged product specific heat capacity – kJ/(kg.K)
α = heat transfer resistance – W/(m². K)
e = EPS packaging wall thickness – m
λ = packaging material thermal conductivity – W/(m.K)
S = EPS packaging internal surface – m²
θ_e = room temperature – °C
θ_0 = product's initial temperature – °C
θ_1 = product's final temperature after Δt time – °C

Example 1: Application of minimum thickness calculation to an EPS box used as packaging for 500g of sausage meat in order to accommodate ruptures in the cold chain lasting no longer than 45 minutes.

	Basis for calculation	Value	Unit of measurement
Δt	Duration of ruptures in the cold chain	0.75	h
m_P	sausage meat packaged weight	0.500	kg
c_P	sausage meat specific heat capacity	2.13	kJ/(kg.K)
α	heat transfer resistance of an EPS wall in contact with air	2	W/(m². K)
λ	EPS thermal conductivity with 25g/l (at + 10°C) density	0.034	W/(m. K)
S	EPS packaging internal surface (size in mm: 165 x 120 x 35)	0.06	m²
θ_e	expected room temperature during breaks in the cold chain	+20	°C
θ_0	sausage meat initial temperature at packaging	±0	°C
θ_1	sausage meat final allowable temperature (by order of 20/07/98)	+4	°C



$$e = 0{,}034 \cdot \left(\frac{0{,}75 \cdot 0{,}06 \cdot 3{,}6}{0{,}500 \cdot 2{,}13 \cdot \ln \frac{20-0}{20-4}} - \frac{1}{2} \right)$$

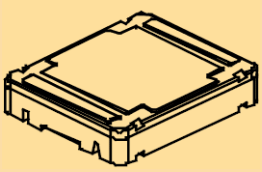
e = 0,006 m

Therefore EPS Packaging wall thickness must be at least **6mm**

How long does thermal insulation last in an EPS packaging with cooling element?

Example 2: Application of thermal insulation period to an EPS box used as packaging for 6kg of fresh fish with 2kg of ice.

	Basis for calculation	Value	Unit of measurement
e	average thickness of EPS packaging walls	0.02	m
m_g	quantity of ice used to chill the fresh fish	2	kg
c_g	ice heat of fusion	335	kJ/kg
α	heat transfer resistance of an EPS wall in contact with air	2	W/(m². K)
λ	EPS packaging thermal conductivity with 18g/l (at + 10°C) density	0.036	W/(m. K)
S	EPS packaging internal surface (size in mm: 380 x 320 x 100)	0.38	m²
θ_e	room temperature during storage	+20	°C
θ_1	EPS packaging internal temperature when filled with melting ice	±3	°C



$$\Delta t = 2 \cdot 335 \cdot \left(\frac{\frac{1}{2} + \frac{0{,}02}{0{,}036}}{0{,}38 \cdot 3{,}6} \cdot \frac{1}{20 - 3} \right)$$

Δt = 30.4 hours

Therefore EPS packaging provides **30 hours** of thermal insulation

A cooling element is often added to EPS packaging in order to increase the period of thermal insulation. The fish products sector generally uses melting ice.

In this case, as long as the ice has not totally melted, the thermal gradient between the content of the packaging and its surroundings stays constant (in other words, product temperature is maintained until the ice has not totally melted).

If transport and storage conditions are known, the period of thermal insulation expected from EPS packaging can be determined. This period corresponds to however long it takes for the ice to melt totally. This can be calculated with the following formula.

Calculation of the period of thermal insulation expected from an EPS packaging – WITH cooling element –

$$\Delta t = m_g \cdot c_g \cdot \left(\frac{1}{\alpha} + \frac{e}{\lambda} \cdot \frac{1}{\theta_e - \theta_i} \right)$$

Δt = thermal insulation period – hours
m_g = cooling element weight – kg
c_g = cooling element heat of fusion – kJ/kg
α = heat transfer resistance – W/(m². K)
e = EPS packaging wall thickness – m
λ = packaging material thermal conductivity – W/(m.K)
S = EPS packaging internal surface – m²
θ_e = room temperature – °C
θ_i = *EPS packaging internal temperature when filled with cooling element* – °C

Use of alignment chart to calculate wall thickness:

1 – Calculate the value of ratio $\frac{\theta_e - \theta_1}{\theta_e - \theta_0}$
2 – Choose the corresponding curve
3 – Read on the diagram the value of wall coefficient c_e relative to the period of thermal insulation Δt needed for your products.

Your EPS packaging thickness corresponds to: $e = c_e \cdot \frac{S}{m_p \cdot c_p} - 0{,}0175$

Calculation based on Example 1 from previous page:

Ratio $\frac{\theta_e - \theta_1}{\theta_e - \theta_0} = \frac{20 - 4}{20 - 0} = 0{,}8$
Chose the red curve 0,8
If Δt = 0,75, the diagram shows that : $c_e = 0{,}42$

S = 0.06 $m_p = 0.500$ $C_p = 2.13$

The EPS packaging thickness corresponds to: $e = 0{,}42 \cdot \frac{0{,}06}{0{,}500 \cdot 2{,}13} - 0{,}0175$

e = 0.006 m, **so e = 6 mm**

Use of alignment chart to calculate insulation period:

1 – Calculate the value of wall coefficient $c_e = (e + 0{,}0175) \cdot \frac{m_p \cdot c_p}{S}$
2 – Calculate the value of ratio $\frac{\theta_e - \theta_1}{\theta_e - \theta_0}$
3 – Choose the corresponding curve
4 – Read on the diagram the period of thermal insulation Δt corresponding to the calculated value of wall coefficient c_e.

(Application à l'emballage de 8 kg de fromage avec :)

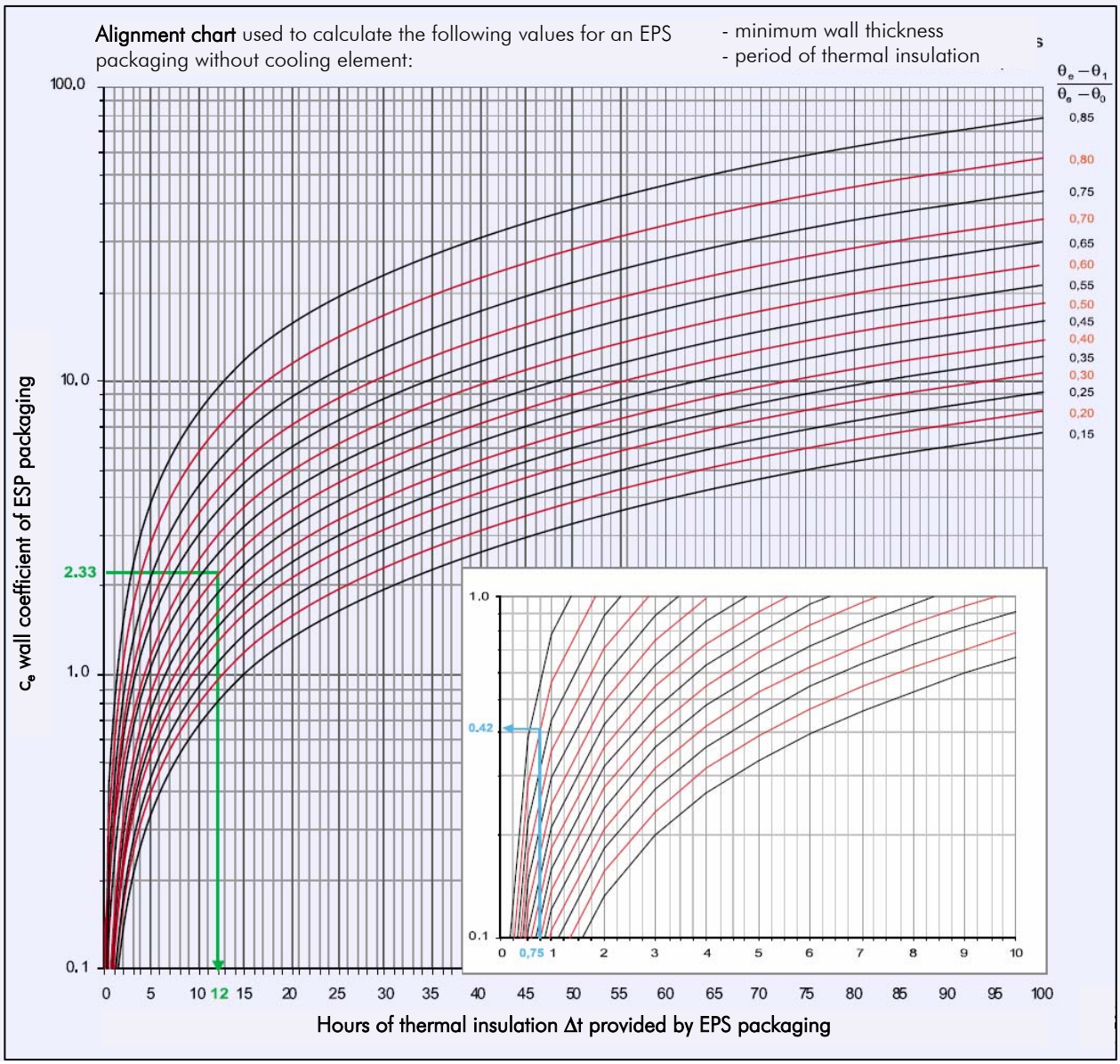
S = 0,36 m² m_p = 8 kg c_p = 2,85 kJ/(kg.K) e = 0,02 m
θ_e = + 20°C θ_0 = ± 0°C θ_1 = + 10°C

$c_e = (0{,}02 + 0{,}0175) \cdot \frac{8 \cdot 2{,}85}{0{,}36} = 2{,}3$

$\frac{\theta_e - \theta_1}{\theta_e - \theta_0} = \frac{20 - 10}{20 - 0} = 0{,}5$

Therefore the diagram shows a period of thermal insulation of: Δt = **12 hours**

Alignment chart used to calculate the following values for an EPS packaging without cooling element:
- minimum wall thickness
- period of thermal insulation



HEALTH: COLD FOR LIFE

The health sector brings together numerous fields in which insulating packaging is required for transport: delicate pharmaceutical drugs, vaccines and medical samples, organs for transplant ……..
Here are three examples.

The cornea before transplant – a multitude of precautions.

Founded in 1948, the French Eye Bank's mission is to supply corneas ready for transplant.

Once removed from the donor, the cornea is placed in a conservation medium in a small bottle, which is then placed in an expanded polystyrene box, designed with different sized wedges so that different sized bottles can be placed in it. Each box can store up to 4 bottles.

No refrigerant is added to this, with transportation taking place at ambient temperature (22°C): the EPS packaging effectively eliminates any risk of thermal shock. Protected in this way the cornea arrives at the laboratory where it is incubated at 31°C in preserving fluid, a procedure which allows it to be kept for 30 days.

After a multitude of bacteriological and serological tests, and repeated verifications of its suitability, the cornea is plunged into a deturgescing medium two days before the hospital's planned transplant date.

This medium designed to eliminate oedema and to render the cornea transparent also serves as the transport liquid. One last journey in a controlled temperature, placed under the double protection of a new EPS packaging and a thermostatically controlled room then awaits the cornea: it is essential for the success of the operation that the cornea does not suffer any significant increases or decreases in temperature during transportation or during the short storage time before the transplant.

Protecting vaccines from tropical heat

The consignment of medical biopsies, samples and strains is not a rough science.

This is particularly true when the transportation is from one tropical zone to another, such as the case of the vaccines sent out by the Pasteur Institute in Dakar to Latin America, for example. Three millilitre ampoules of lyophilised vaccine are packed by 10 in a case, explains Dr. Dramé.

"We then place them in a 38x54x46cm EPS box which is half filled with carbo-ice and half filled with vaccines, 4kg of carbo-ice to 100 cardboard cases of vaccine. The box is then sealed before consignment and the vaccines are maintained at an adequate temperature for 72 hours.

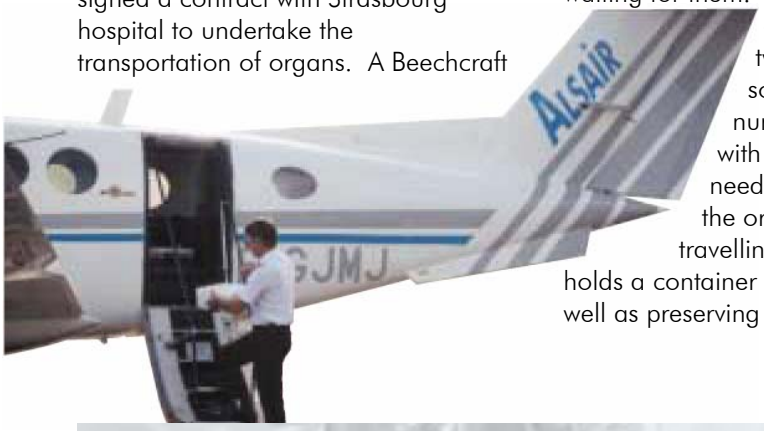
In order to check that the temperature remains below the maximum acceptable temperature, a cold chain monitor is inserted in each EPS box.

It is a simple packaging which meets rigorous requirements.

Preparations for a consignment of yellow fever vaccines for Abidjan.

Organ transportation: speed and thermal protection

For a hospital, organ transplantation implies the implementation of two essential and integral elements: speed of transportation and protected refrigeration during consignment.
So how are both of these requirements met…..?
The site of organ removal and that of its subsequent transplantation are very frequently far apart. In order to reduce the time between the two operations, the hospital naturally works closely with an airline company.
Jean-Marie Joubert, a pilot with the airline ALSAIR explains: "Having tendered for the work, our company signed a contract with Strasbourg hospital to undertake the transportation of organs. A Beechcraft is available at Colmar Houssen airport for the CHU (University hospital) 24 hours a day, 7 days a week." As soon as Strasbourg hospital is contacted by the EFG (Etablissement Français des Greffes – French Organ Transplantation Authority) regarding the removal of an organ, everyone swings into action.



- Strasbourg CHU's co-ordinating nurse calls to book the flight with the airline company.
- Within 3 hours Strasbourg CHU's specialist organ removal and transplantation team arrives at Entzheim airport, where ALSAIR is waiting for them. The team is most often made up of two surgeons, and sometimes a nurse, who board with the equipment needed to remove the organ and a travelling cool box which holds a container for the organ as well as preserving fluid.

- The CHU team arrives at the airport nearest to the site where the organ will be removed. The ALSAIR plane waits for them. It then takes off between one and four hours later for Entzheim/Strasbourg with the organ for transplant.
- On landing the medical team is immediately picked up by taxi. The organ for transplant, which has travelled at low temperature in the cool box from the time it was removed, is then transplanted in the recipient within hours.

SPECIAL CONTAINERS FOR ORGAN TRANSPORTATION

With its bulky exterior the cool box used for the transportation of organs looks like a family's camping ice-box. Inside there is a sterile container with preserving fluid, ready for the organ – and a sterile plastic box if it is for the heart or blood vessels (veins or arteries), or a stainless steel metal box for the liver.

Crushed ice maintains refrigeration conditions for the organ, ensuring a temperature of 4°C for the duration of the flight until the organ is transplanted.

In the case of removal and transplantation of a kidney (or pancreas), a specific EPS based packaging is used.

In the case of the kidney, it is first immersed in a jar filled with preserving liquid. This jar is then placed in an EPS tubular container designed specifically for this purpose, and for which the specifications are set out by the French Organ Transplantation Authority. Ice is added so as to cover totally the exterior of the jar, and the container is then closed using adhesive tape. The kidney is thus protected by EPS's double property of insulation and resistance against shocks.

These two conditions allow it to be dispatched in total safety and simplicity via plane as well as train.
Moreover, in the majority of cases, the kidney can simply be handed over to the transport staff.

COLD'S BIOLOGY – THE CASE OF THE SARDINE

Salting, smoking, drying … preserving food has always been one of mankind's concerns. Preservation using cold is today's preferred option as it allows food to keep a maximum of its qualities. But there is cold and cold, and controlling the amount of time food can be preserved can not be managed 100 per cent …..It is still difficult for certain food types, in particular for blue fish, such as sardines and anchovies.

It is well known that the cold inhibits the multiplication of bacteria, and the lower the temperature, the longer the inhibition lasts. This phenomenon is due to the fact that cold reduces the molecular activity of the water contained in the foodstuff, which consequently slows the functioning of the organic or bacterial enzymes, or even stops them altogether in the case of freezing or quick freezing.

However, neither maintaining a low temperature, freezing nor quick freezing can eliminate lipid oxidation and thus stop fats going rancid if there is inappropriate hygrometry. This is why sardines cannot be frozen or quick frozen, for example. Among fresh fish, which is all highly sensitive to enzyme attack, the sardine in particular deteriorates even more quickly, because of its muscular fragility and its skin which is very susceptible to tearing. The slightest pressure is enough to spoil it, making it unfit for sale. Moreover, this blue fish has a rapid metabolic rate, making it impossible to gut, and even when dead, its enzymes remain active, which explains the rapidity with which its organoleptic qualities are altered. This is why it is necessary to introduce cold as early as possible: Hansen and Jensen's studies of 1982* showed that if the sardine was refrigerated immediately after being caught it kept 4 days more than if it had been cooled 5 hours afterwards. Thus the common practice in the Mediterranean consists of placing sardines in containers filled with fresh water ice. In the south of the Iberian peninsula, fished sardines have for a long time been placed in wooden containers, 12 to 14kg per container with a small amount of ice, a practice which entailed wastage. But transport in wooden packaging, including in the countries of southern Europe, has nowadays largely been replaced by EPS, which is known to be more effective. This is confirmed by the results of a study carried out by the Cold Institute in Madrid with a university team from the Department of Fishery Products (December 1999). This study evaluated, in technical and sanitary terms, the efficiency of the preparation and transport systems used by sardine exporters in southern Spain, by comparing wooden container packaging and EPS. One batch of sardines was stored with ice in wooden containers, two others in EPS containers, one in ice with ice water flow, the other in brine (a mixture of salt water and ice). The three batches of sardines were then transported from Cadix to MercaMadrid (the Spanish equivalent of Rungis) in insulated lorries.

The study illustrated that for the batches cooled in the EPS containers, the sardines were subjected to a rapid reduction in temperature, and arrived at MercaMadrid at 2°C. On the other hand, the sardines in the wooden containers arrived at temperatures varying from 4 to 8°C, according to the fishing season.

What is more, the study also revealed that the rate of bacterial development was lower with EPS, which confirms its place, once and for all, as the most suitable material for the fresh fish market.

EPS combines three essential properties:

- Insulating packaging, which ensures optimal temperature conditions
- An inert packaging, which does not contribute to bacterial development
- A protective packaging, which helps prevent all mechanical deterioration of superficial tissues.

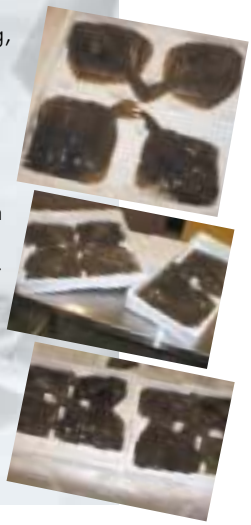
In short, it has all the features which meet hygiene criteria specified by European regulation.

*Hansen and Jensen (1982), Bulk handling and chilling of large catches of small fish, Infofish Market Dig, 6,26-28.

TURBOTS: TRANSPORTED WITHOUT WATER, THEY ARRIVE ALIVE IN CHINA

Part of the Adrien group, France Turbot exports live turbots and is particularly involved in producing young fish. The company is well versed in cold biology and logistics chain control. Bred and caught in Noirmoutier, in the company's fish tanks, the turbots are placed in water filled aluminium containers before being transferred to a platform where they are prepared for consignment without water. After a few days without food and during which their body temperature is progressively lowered, the turbots are kept at low temperature and dispatched to France Turbot's export site, at Roissy's cargo area. Just a few hours after take off, they are transferred to specially moulded EPS trays which are also wrapped in EPS packaging patented by France Turbot. "Each tray can contain two to four marketable size fish (600g to 1.2 kg)", explains Bruno Justome, project manager. "We've chosen this material because it maintains the temperature inside the box and because it gives a good thermal insulating property/ volume-weight ratio. And that's a definite advantage in our business. Turbots are 95% guaranteed to reach their destination alive after spending 24 hours in a dry container. We've even had better results over longer periods, but this performance is good enough for us to export our fish worldwide. As world leader in controlled reproduction of turbots and as the only producer to have acquired the know-how needed to ensure the fish can be dispatched alive and dry, we work extensively with China, where we send our alevins for breeding, using mainly the same waterless process.

" Very fond of fresh sea products, Japanese clients also buy the French company's turbots in marketable sizes. Once 'awakened', these fish end up in a retailer's or a restaurateur's fish tank until such time as a client wishes to indulge in a super fresh portion of turbot.



EPS: KING OF PROTECTION FOR FRUIT AND VEG

The FAO's world summit held in Rome in 1996 reminded us of the huge quantities of fruit and vegetables wasted worldwide after harvest. As many studies have shown, using adequate packaging would drastically reduce these quantities. Here is an overview of some of them…

Prevention of post-harvest losses: fruits, vegetables and root crops and tubers. This is the title of a training manual published in 1992 by the Food and Agriculture Organization of the United Nations (FAO) and the Information Network on Post-harvest Operations (INPhO), in which the issue is presented in the following terms: "In spite of remarkable increases in world food production, nearly half of the population of third world countries does not have enough to eat. Although there are many reasons for this, the quantities of food wasted post-harvest and at the different stages of the marketing process is one of them." Estimated at around 10 to 15% in industrialised countries, these losses may reach 30 to 45% of the initial harvest in developing countries, if not more according to various estimates.

In order to help us better understand the reasons for these losses, FAO's study reminds us that the life expectancy of a fruit depends on its water content (65 to 95% initially) and nutrients. The loss of these two attributes leads to a phase of decomposition which several factors can accelerate considerably during harvest, handling, and transport: low air moisture, excessively low or high temperatures, and lesions to which these plants are sensitive because of their high water content. Lesions (external and internal) increase the plant's respiratory activity provoking an increase in heat release, while water loss is due mainly to external lesions. The study published by FAO and INPhO indicates what should be *avoided "so that the packaging itself does not damage the products being* handled". It must have no splinters, staples, or nails sticking out, and should be able to resist perforation. Its shape should make it easy to assemble and stack, especially as "losses occurring as a direct result of transport conditions can be very high indeed. (…) Produce placed in JT or nets is particularly vulnerable to deterioration and shock. (…) Humidity and water soon cause cardboard boxes to soften up and lose their intended shape. (…) Produce packed in wet bags, boxes or cartons deteriorates more quickly. (…) As a general rule, packaging does not provide adequate insulation, nor does it help much to stop damage caused by cold or heat. Lack of ventilation in packaging slows down the cooling process and can force the content to produce its own heat, increasing water content loss and natural decomposition. Recently developed expanded polystyrene packaging has good insulating properties and is used, with ice, to transport vegetables characterized by high respiratory activity". Two other studies confirm these findings. Carried out in 1997 by Dr. Hyung Woo Park at the Korean Food Research Institute, the first study shows that EPS packaging remains the most efficient material for storing fruit and vegetables. The outcome of the study over one week (see table) shows that EPS reduces content weight loss and preserves its nutrients.

Percentage of remaining vitamin C after one week of storage

	STORED IN CORRUGATED CARDBOARD PACKAGING	STORED IN EPS PACKAGING
COURGETTES	41.30%	85.28%
CUCUMBERS	54.72%	68.87%
TOMATOES	80.71%	92.42%
GRAPES	44.52%	85.87%

In particular, EPS packaging preserved up to 44% more vitamin C, *a highly volatile and fragile antioxidant,* in certain vegetables, and from 6 to 41% more in some types of fruit (apples, pears and grapes) than a simple corrugated cardboard box. Dr Park's study also highlights EPS's superior performance in terms of preventing post-harvest losses due to fruit and vegetable bruising.
The outcome of tests carried out in 1992 by the packaging division at Michigan University confirms his conclusions and that of the FAO/INPhO: bunches of apples packed in various packaging – EPS trays, papier mâché trays and two different types of paper-cardboard packaging – were subjected to a laboratory simulation test recreating the vibrations of a freight lorry. Published in Packaging Technology and Science, the results of these tests expressed in percentages of bruised fruit and numbers of damaged areas on the pieces of fruit themselves, put EPS ahead of other materials in terms of protection of contents during consignment.
Two international events, namely the 10th Post-harvest Convention held at Cranfield University (UK) in March 2000 on packaging and the Convention Internationale de l'IIR (International Institute of Refrigeration) held in Murcia (Spain) in 2000 on post-harvest technological improvements of fruit and vegetables show that these issues are still topical.

METRO: Ready-to-use solutions to maintain the cold chain

A wholesaler that welcomes customers into warehouses which are all structured on a single working model, METRO's basic philosophy is customer service – customers who are catering professionals and subject to the 1998 transport decree, regulating the transport of fresh and frozen goods. In order to help customers with compliance, METRO makes reasonably priced transport solutions available to them – approved containers and refrigerants adapted to their needs. The distributor thus offers professional insulating containers for fresh and frozen produce: 810 litres being the largest; 85, 68 and 55 litres for intermediate capacity, and 43.5 litres for EPS boxes. The regulatory temperature is maintained using cold diffusers or eutectic plates which can be exchanged free of charged at distributors designed for this purpose. The concept's success proves that METRO correctly anticipated the market's direction: the need for insulating protection is attracting more and more professionals – the demand for EPS boxes, for example, has seen an increase of almost 60% in three years.

A delivery of perfect strawberries

Extremely perishable by definition, strawberries and raspberries are always placed in an air-conditioned area after picking, where they remain for quality control and packing in punnets.

It is once this has been completed that the problems begin, as any variation in temperature during transport can be fatal. It is a common problem for which EPS can now offer a solution. Cadram de Marmande, producers of 'gariguettes' (a variety of strawberry) in South-West France (the main production area for quality strawberries in France) place their punnets of strawberries in EPS packing cases with 12 cavities, the bottom of which, serving also as a cover, contains thermal stabilisers.

The EPS thus acts both as a thermal and water "buffer": as the loss of frigories is compensated during consignment, and a constant level of temperature is assured right to the point of sale.

600x400 mm in dimension, these EPS packing cases suitable for stacking and palletisation help strawberry producers in their quest for quality. The intense interest displayed by 'Etablissements Marionnet' for their 'Mara des Bois' variety, a close relative of the wild strawberry, which is very sensitive to heat, gives confirmation, as if it were needed, of how extremely efficient this type of packaging is in preserving contents' gustatory quality.

This is not all: EPS packing cases are opening new avenues for the market, which from now onwards could move away from its seasonal limitations. As this fruit could, for example, be transported safely from North Africa, it may soon be possible to eat quality strawberries all year round.

EPS, the indispensable "e-commerce" material

Orders for fresh produce via the "net" are starting to expand……. But how can a fresh or frozen product be sent rapidly will avoiding the extra costs of using a refrigerated vehicle?

In effect, food that must be kept at a temperature between 0 and 4°C must not in any way exceed this temperature during its transport, nor can it be subjected to a temperature of less than 0°C, as this would freeze it. The ideal solution is the "fresh box", an EPS box designed for Messer, a supplier of refrigerants, and the sixth largest producer of industrial gases in the world. Ranging in capacity from 16 to 60 litres, the box has a cover whose inner partition can be filled with carbon dioxide snow, the compartments are thus maintained at a uniform temperature for 48 hours – the maximum time limit for consignment by standard courier service, even though the insulation of the *"fresh box" will last up to 72 hours. The box's combined*

properties – hygiene, protection, insulation – make it ideal for ultra-fresh food (meat, packaged fish, poultry) and also mean it can be used in areas with equally rigorous requirements, such as organ banks and pharmacy, which need the cold chain to be maintained while using standard courier services.

A demanding market, the top range container

It is not by chance that the EPS container dominates the meat and poultry market. The implementation of

its two intrinsic properties – insulation and hygiene - continue to be constantly improved by the manufacturers' research teams. At the request of the market leaders (Socopa, Bigard, Charal and Soviba, etc) the container's level of insulation has been significantly increased, in order to provide better protection for particularly sensitive meats such as minced steaks. The container's exterior volume has been reduced so that the meat is more tightly contained, this new geometry ensuring better cold chain control.

This control is also reinforced by the extra thickness of the container's base, while the embossing of the container contributes to the cooling of the produce during packaging.

Another consequence of this is that drip is no longer evident when the container is put on display at an angle of 45°.
As a result of logistic constraints, it is obviously designed to be stacked without damaging the contents in any way: an additional benefit when it is put on display….

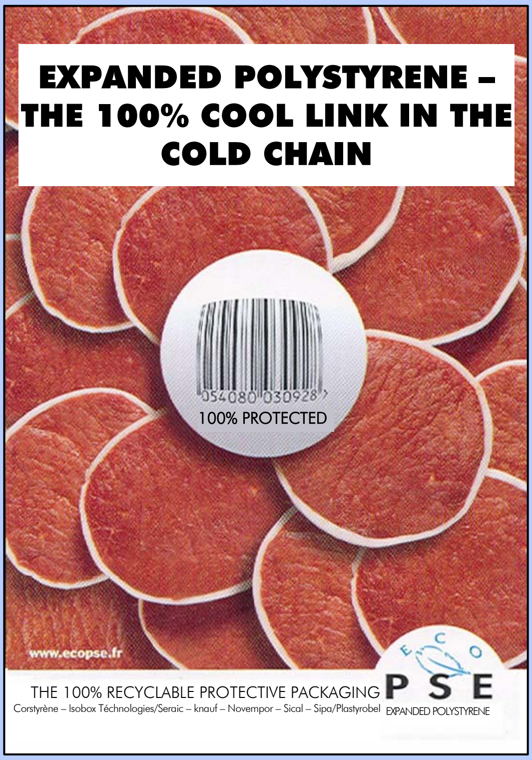
An EPS packaging designed for seafood logistics

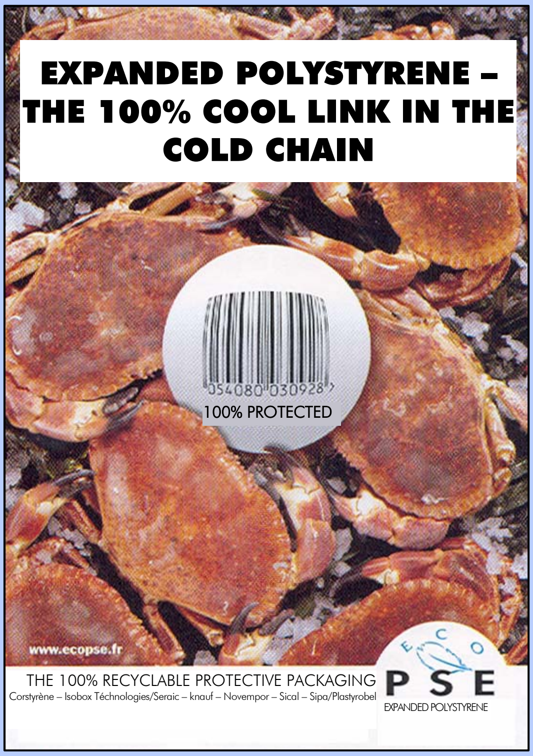
Krustanord, the specialist in seafood such as prawns, has just patented the Isopack, an EPS ring developed in partnership with its supplier. "Our range of prawns packed in containers under protective atmosphere were previously stored together in a box," explains André Bellaiche, Director of the Lorient factory (of the company's three plants, this is the one specially dedicated to top of the range products). "As the containers travelled by sea they were inevitably exposed to moisture and shocks, and consequently arrived in a poor state.

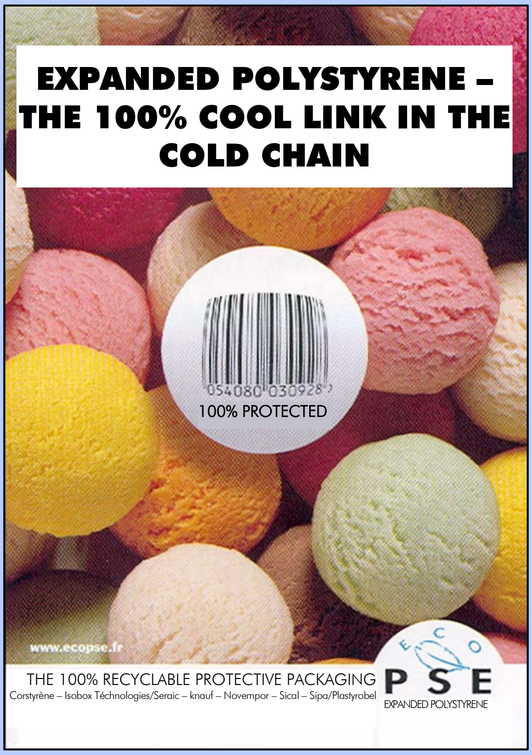
We therefore developed the Isopack (registered trademark), a packaging which consists of an EPS ring with a reinforced interior which can take a 2kg box of prawns. It can also take two 1kg boxes, or even six 150g containers. The ring simply has to be turned in order to adapt it to meet the capacities required." For logistical purposes the rings have been designed to fit into each other: the base also acting as a cover, with five rings plus a base and a cover forming what is know in maritime logistics as a 10kg load.

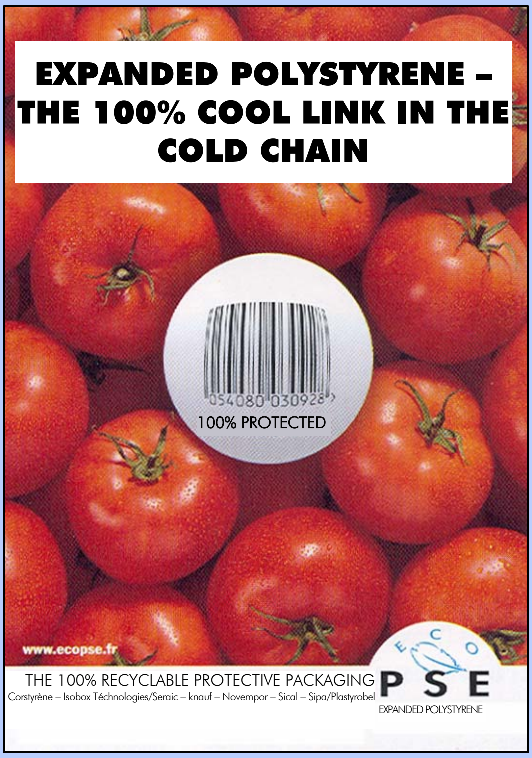
In order to avoid any rupture in the cold chain, the EPS' natural thermal insulation is reinforced with gel packs for the food industry, which are placed on each container. In addition, the packaging can be as easily adapted to meet the needs of large supermarkets as it can to meet those of small retail outlets or restaurant owners. The EPS Isopack's insulating and anti-shock properties also make it suitable for the export of foods for which the respect of the cold chain is particularly important.

EXPANDED POLYSTYRENE'S COLD CHAIN CAMPAIGN









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