White Paper - Parker nitrogen gas generation for Modified Atmosphere Packaging, (MAP).

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Modified atmosphere packaging (MAP) is a process where the Earth's atmospheric gas ratio at sea level is altered to provide beneficial food preservation properties within packaged produce. The aim of MAP is to prevent or slow down food spoilage mechanisms that alter the appearance, smell, taste, shelf life and safety of the product.

Typical composition of air at mean sea level

Gas	Symbol	Volume in Air %
Nitrogen	N_2	78.084
Oxygen	O_2	20.9476
Argon	Ar	0.934
Carbon Dioxide	CO_2	0.0383
Neon	Ne	0.001818
Methane	CH_4	0.0002
Helium	He	0.000524
Krypton	Kr	0.000114
Hydrogen	H_2	0.00005
Nitrous Oxide	N_2O	0.00003
Carbon Monoxide	CO	0.00001
Xenon	Xe	0.0000087
Ozone	O_3	0.000007
Nitrogen Dioxide	NO_2	0.000002
Iodine	I	0.000001
Ammonia	NH_3	Trace

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Food Spoilage Mechanisms

Oxidation

When fats and oils within food come into contact with atmospheric oxygen, oxidative rancidity can occur. This results in the food taking on an objectionable and unpleasant taste and or odor.

These fats and oils can either occur naturally as a component of the product, such as milk powder and coffee, or as a residue from processing or cooking, such as fried potato chips.

Some of the naturally occurring vitamins and minerals within food products are oxidised in the presence of atmospheric oxygen, reducing their beneficial health properties.

When certain types of fruits and vegetables are cut or sliced, enzymatic browning happens to the exposed internal flesh as a reaction to atmospheric oxygen.

By excluding atmospheric air and hence oxygen from the finish packaged product, the effects of oxidation can be greatly reduced or eradicated.

Moisture Gain

Atmospheric air contains moisture in the form of water vapor or humidity. If packed in ambient conditions, certain dry food products can absorb the moisture from the air trapped in the pack and become soggy and spoilt.

Parker nitrogen generators produce gas that is extremely dry, containing less than1-2ppmv water vapor. Using gas this dry for MAP prevents moisture sensitive food from becoming ruined.

It is also very important that the packing film, used for dry products, acts as a barrier to prevent the transmission of water vapor from atmospheric air through the packaging material and into the product once it is packed.

Microorganisms

Bacteria, moulds and yeasts come under the general description of microorganisms and can be categorized by how their oxygen interaction facilitates metabolic and reproduction processes.

Typical food borne micro-organisms such as – Certain strains of Pseudomonas, Escherichia Coli, Staphylococcus Aureus, Salmonella, Clostridium Botulinum, Clostridium Perfringens, Bacillus Cereus, Vibrio Parahaemolyticus, Listeria, Yersinia Enterocolitica and Campylobacter, can cause food spoilage as well as food poisoning in humans with mild to very serious or even fatal consequences.

Microorganisms are living cells needing to produce Adenosine Triphosphate, (ATP), a complex organic chemical found in all forms of life, to create energy and drive their propagation.

Some species of microorganism need oxygen for aerobic respiration to create ATP, others can produce ATP by fermentation without the need for oxygen, and some can switch between aerobic respiration or fermentation to adapt to their environment.

There are four main groups of microbes where modified atmosphere packaging can play a part in controlling their effect on food products

Aerobic –
Need the oxygen contained within air for respiration and propagation. Using nitrogen to displace oxygen or air within bulk storage, processing and packing helps to retard the growth of this type of microorganisms.

Anaerobic –
Do not need oxygen for respiration and can be inhibited or destroyed by even small quantities of oxygen.

Facultative Anaerobic –
Can live and propagate with or without the presence of oxygen, producing ATP by aerobic respiration or fermentation.

Microaerophilic -
Need low levels of oxygen to provide optimum growth potential. Some also need raised levels of carbon dioxide too.

Modified Atmosphere Packaging Gases

The three main gas species used are - Carbon Dioxide, (CO_2), Nitrogen, (N_2) and Oxygen, (O_2).

Carbon dioxide – (E290)

CO_2 is used in MAP for its anti-microbial properties. Naturally occurring in ambient air at approximately 400ppm, the levels used in modified atmosphere packaging can range from 20% to 100%.

Most commonly it is combined with nitrogen at 30% to 40% to inhibit anaerobic spoilage mechanisms.

Due to its relatively high solubility, it easily dissolves into the moisture and fat of food products. In relation to the moisture phase, CO_2 lowers the PH level very slightly, creating carbonic acid. This can have beneficial effects with certain food products where the spoilage mechanisms are Gram-Negative bacteria, such as Pseudomonas.

Because CO_2 has a high water solubility rate however, it can cause problems with modified atmosphere packaging if used in very high concentrations. The CO_2 can be absorbed into the food product, creating a partial vacuum, resulting in undesirable pack collapse. To prevent this happening carbon dioxide is often used in combination with nitrogen to act as a filler gas. Being approximately 100 times less soluble than CO_2, nitrogen will not dissolve into the product as readily and the pack will retain its intended shape.

Gas to product ratio -

According to Campden BRI, who provide scientific, technical and advisory services to the food and drink industries:

It is important not to overlook the gas to product ratio. Not to be confused with the composition of gas, rather, this is the actual volume of the gas added to the pack. Because carbon dioxide is easily absorbed into the product, it is important to get a sufficient quantity of gas into the pack for it to be effective. Depending on the product, Campden BRI recommended that a 2:1 gas to product ratio is used.

Oxygen – (E948)

Normally oxygen is an undesirable gas to have present within the packaging process, however, with some meat, fresh fruit and vegetable products it can have a positive effect.

Red meat can benefit from high levels of oxygen, in the region of 70% to 80% to oxygenate the purple myoglobin, that give uncooked meat its brownish appearance, to create oxymyoglobin, so the meat appears red and "fresh".

Whole and prepared fruit, vegetables and salad produce, absorb oxygen through respiration and produce carbon dioxide as a waste gas. Reducing the package levels of oxygen to approximately 5%, (depending on product), helps to slow the metabolism of the produce and hence the respiration rate. This helps maintain an aerobic atmosphere within the pack, delaying the potential for anerobic fermentation and hence the shelf life and appearance of the produce.

Nitrogen – (E941)

Nitrogen is an inert gas that is used in food and beverage applications to primarily displace ambient air and thus the oxygen present at 20.9%.

Displacing ambient air has many beneficial effects on the MAP of food products, such as preventing enzymatic browning and oxidative rancidity as well as retarding the growth of certain aerobic microorganisms.

Nitrogen is also used as a filler gas to prevent pack collapse. This is important to retain the protection of relatively fragile food products within their "pillow packs" such as potato chips for example, as well as the desired shape of the finished product.

Most dried products, typically nuts, potato chips, extruded snacks, spices etc., can be packed in a 100% nitrogen atmosphere without the need for any other gases.

Other gases with "E" numbers

Nitrous Oxide NO_2 (E942) – generally used as a propellant for aerosol cream.

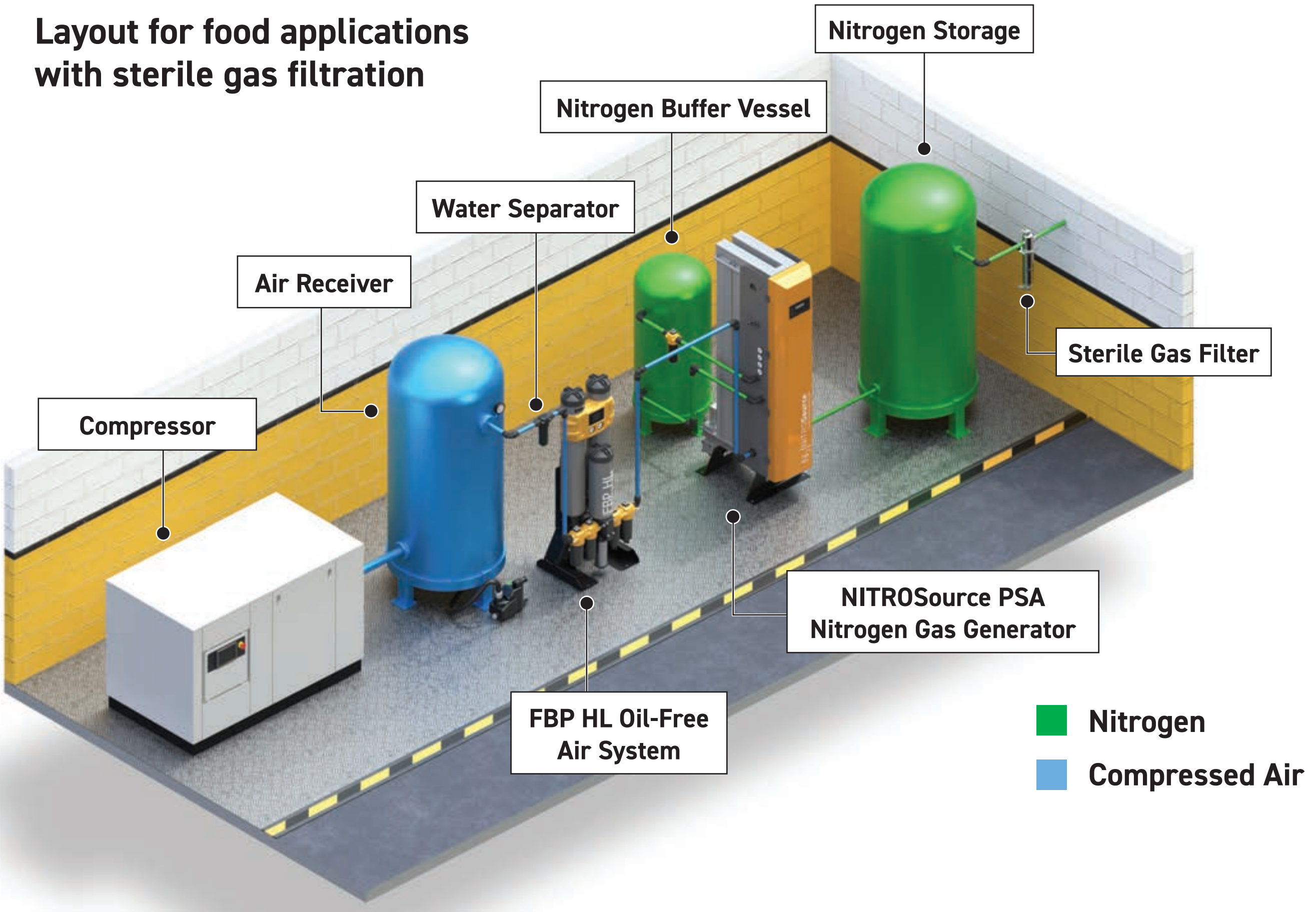
Argon Ar (**E938**) – no real benefits over nitrogen in MAP. Extremely costly.

Hydrogen (E949) – used for hydrogenation of fats and oils.

Helium (E939) – used for some canning processes but no real application for MAP.

Carbon Monoxide CO – is used in some countries to package red meat but is not an EU approved food additive so cannot be used in European Union countries.

Layout for food applications with sterile gas filtration



Gas Sterility

Nitrogen gas produced from a Parker nitrogen generator can be considered commercially sterile. The use of a Parker desiccant dryer based compressed air pre-treatment ensures the inlet air to the generator is food grade and at a pressure dew point of -40 degrees centigrade. It is widely recognized that a pressure dew point of -26 degrees centigrade will inhibit bacterial growth.

Food packing machines, films, materials and food products, while normally under hygienic regimes to GMP food standards, are not generally produced, stored or operated in sterile clean room atmospheres. At over 400,000 times cleaner than ambient air, the generated nitrogen gas is probably the most sterile component of the MAP process.

Additional point of use or whole system, sterile filtration can be used if required to ensure microbial protection to 0.2 microns in size.

Nitrogen Gas Purity

Within the European Union the specification for nitrogen gas used as a food additive for the process of modified atmosphere packaging, must comply with directive 231/2012 of the 9th of March 2012 laying down purity criteria for the gas and designating an "E" number. Nitrogen is designated "E941".

Guidelines on the "Safe design and operation of on-site nitrogen generators for food use" produced by the European Industrial Gases Association, EIGA, defines the specification for E941 and can be found in their publication "Doc 194/15"

EIGA

Food Additive E941 specification purity limits –

Commission Regulation (EU) No 231/2012 of 9th March 2012

Laying down specifications for food additives listed in Annexes II & III to Regulation (EC) No 1333/2008 of the European Parliament and of the Council

Nitrogen ≥ 99% v*
Oxygen ≤ 1% v
Water ≤ 0.05% v (500ppmV)

*99% including other inert gases such as noble gases (argon mainly)

Impurities:

Carbon monoxide	*≤10 ppmV*
Methane and other hydrocarbons (as methane)	*≤100 ppmV*
Nitrogen monoxide and nitrogen dioxide	*≤ 10 ppmV*

Final packaged product - minimum oxygen concentration

While the minimum purity of the gas produced by the nitrogen generator is specified exactly, the maximum remaining oxygen concentration within the pack can vary greatly. There are many factors that can influence this. Generally, a food producer using modified atmosphere packaging defines an acceptable level of remaining oxygen based upon food type, spoilage mechanisms and expected shelf life. Typically, achieved levels of between 1% and 4% oxygen are sufficient to prolong shelf or storage life depending on the food product.

Why is there a difference between gas and pack oxygen content?

Considering packing processes that utilize a gas flush, whereby the ambient air is removed from the pack by the motive force and volume of the flushing gas, such as vertical, form, fill and seal technology; it is virtually impossible to fully remove all of the ambient air, hence some oxygen remains. Also, as the product is dropped from the multi-head weigher into the hopper and enters into the packaging material, it also draws ambient air in with it. Therefore, the pack oxygen content is always higher than the flushing gas for most applications.

Difference between liquid nitrogen and food grade generated gas

Typically, the oxygen content of liquid and cylinder nitrogen is in the region of 10ppmv. The specification for food grade nitrogen is <1% oxygen content. Does this purity disparity create a real difference in the finished pack?

The challenge facing many food and beverage producers is to be as competitive as possible without compromising product safety and quality. The huge cost benefits that can be realized by using on-site nitrogen generation compared to traditional methods of supply are extremely appealing, however, sometimes questions focussed on the difference in oxygen content need to be addressed, allaying concerns that a company's produce and reputation are not compromised or jeopardized.

Installing a trial nitrogen generation system might appear to be a logical solution but it is not always practical or viable to do so, especially when the nitrogen flow demand is high or there are space limitations.

Parker have a multitude of food and beverage references and application articles covering a very broad range of food products and processes too, but occasionally only proof of suitability with the customer's actual product and packing machine(s) will suffice.

Case Study - Parker Generated Food Grade Nitrogen vs. Liquid Nitrogen Trial

2017 - Parker were invited to advise on the suitability of nitrogen gas generation for a high-quality coffee producer based in the UK.

Existing installation -

Bulk liquid vessel with evaporator, 25 years old. Maximum flow demand 165m^3/h (97 scfm).

Considerations –

- Ongoing escalation in gas prices and delivery reliability for existing liquid supply.
- Proposed generated nitrogen gas supply must have absolutely zero impact on the taste, shelf life and quality of the product.
- Unequivocal proof required of gas purity and suitability using customers equipment, product and QA department acceptance.
- Target generated gas purity 0.5%
- Maximum remaining oxygen content in the finished pack <2%
- No possibility of operating a trial due to limited space availability.

Solution

Parker designed and commissioned the construction a device called a "nitrogen diluter". This utilized the existing high purity liquid nitrogen supply and bled a small amount of food grade compressed air into the high purity gas stream to raise the oxygen content and simulate the purities being proposed for nitrogen gas generation. The trial was carried out on one packing line and only the high purity gas feed to this line was modified. This ensured minimum disruption, while the rest of the factory continued to operate from the existing supply. A calibrated external oxygen analyzer was used to measure the purity of the gas as it entered the packing machine to confirm the correct oxygen set point and a calibrated flow meter ensured the gas flush flow was equal under all conditions.

Three production batches of coffee were produced, one at 10ppm using the evaporated liquid nitrogen only, and two at 0.1% and 0.5% oxygen content using the evaporated liquid blended with food grade compressed air using the nitrogen diluter system.

Samples were taken from each batch and tested by the company's quality assurance department, using a calibrated table top MAP gas analyzer to check the maximum remaining oxygen content within the pack, against a maximum target of 2%.

	Batch sample test									
O_2 Level	1	2	3	4	5	6	7	8		
	MROC levels								MROC target	Flow l/min
10ppm	1.0	0.8	0.8	1.2	0.4	0.7	1.3	1.0	2%	310
0,1%	0.7	0.7	0.5	1.2	0.8	1.4	1.1	1.1	2%	310
0,5%	1.0	1.0	1.0	1.1	1.0	1.4	1.2	1.2	2%	310

Nitrogen diluter used for the coffee pack maximum residual oxygen trial.

The test results clearly demonstrate that despite the increase in flushing gas oxygen content from 10ppmv to 0.5%v, the coffee pack maximum remaining oxygen content remained well below the maximum target level of 2%v.

The trial result was accepted very positively by the company directors and a complete turn-key package with Parker NITROSource generators was subsequently ordered, returning a pay-back on investment in less than 18 months.

MAP Gas Analysis Within the Pack

To determine the gas ratios and purity within the finished packaged product, either bench top or hand-held gas analyzers can be used. Generally, a sample of packs is checked per batch being produced and the gas purity and ratio in the pack measured recorded.

Portable headspace gas analyzer. Monitoring the gas concentrations inside the sealed pack is an essential pre-requisite for ensuring the shelf-life of a gas flushed product. Image courtesy of Tendring Pacific.

Gas Mixing

When the MAP process requires more than one gas, there are several methods of delivering the correct mix ratio.

Traditional mixed gas cylinders are filled with the required gas mix at the cylinder filling plant but can be extremely expensive. If there is more than one gas mix required by the packing company, then this entails stocking cylinders or pallets containing the different ratios.

A very flexible method of delivering more than one species of gas in a MAP application is to use a mixing panel. These are configured for 2 or 3 gas mixes, either as fixed ratio or adjustable versions.

Using a gas mixing panel is an ideal solution when using a nitrogen gas generator because it enables the purchase of lower cost CO_2 cylinders, (when compared to CO_2 + nitrogen mixed gas cylinders), and generated nitrogen to provide the lowest overall mixed gas cost.

Replacing cylinders with on-site nitrogen generation -

Most gas mixing panels are designed to be used with gas cylinders and therefore are set to a relatively high inlet pressure in the region of 10 barg. When the pressure falls below 10barg, the mixing panel low inlet pressure alarm will sound, (where fitted), on the assumption that the gas cylinder is nearly empty and needs changing.

With typical outlet pressures from nitrogen generation systems of between 5-7barg, a mixing panel set to 10 barg inlet pressure will need adjusting to accommodate this. Most mixing panels already in use can be adjusted and new systems will require the lower inlet pressure to be specified with the panel manufacturer / supplier at time of purchase.

Care should be taken, however, to ensure the reduced inlet pressure does not alter the flow rate capability of the mixing panel below that required.

MAP Mix Provectus gas mixing system

One example of a flexible gas mixing system is the "MAP Mix Provectus" (images and details provided courtesy of Tendring Pacific).

This high capacity gas mixer can be used singly on individual packaging lines or piggybacked together with a buffer tank to provide central mixing capability. Available in both two and three gas mix versions it safely mixes any combination of nitrogen, oxygen, carbon dioxide and atmospheric air.

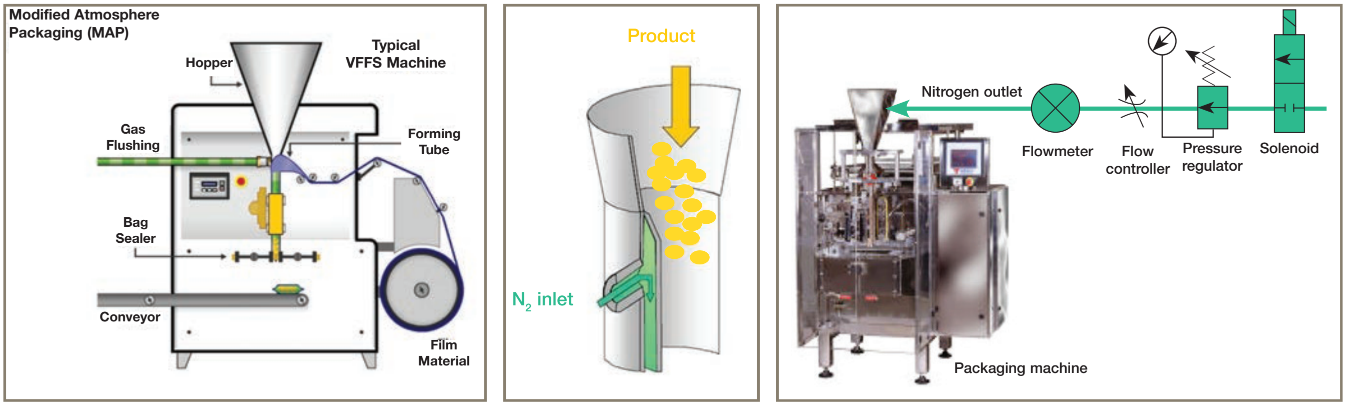
Ideal for mixing gas produced by nitrogen generators as it uses mass flow meters to mix the gases.

These can accurately mix in-feed gases with variable input gas pressures between 2.1 - 10.0 bar. Made possible as this technology works independently of the pressures of the in-feed gases being mixed.

Types of Modified Atmosphere Packing Machines

Vertical, form, fill and seal, (VFFS)

VFFS machines are generally used for dry products that can be dropped into the pack vertically from a multi-head weigher. The pack is formed from a single roll of film that is formed into a bag, filled with product, then sealed by heated jaws and cut into individual packs.



Adaption of hopper and control system for typical VFFS using gas flushing for MAP

The nitrogen gas is generally isolated from the product and directed into the pack to prevent the contents from being blown out of the hopper and or bag.

Typical flow rates associated with VFFS machines is dependent on the pack size, throughput and product with a range commonly between 2-20 m3/h (2-12 scfm) per machine. The gas flushing volume is generally between one to two times the bag volume, again dependent on pack size, throughput and product.

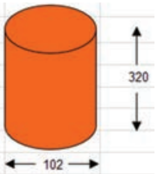
Many VFFS machines manufactured with a gas flushing option, have a control system that often incorporates an adjustable rotometer type flow meter and pressure regulator. These can be housed out of sight, in a control cabinet, but are a useful feature to confirm flow requirements if fitted. Some machines have digital flow meters with inbuilt gas mixing too.

INPUT BAG DATA

Bag Length (mm)	350
Width (mm)	160

INPUT MACHINE DATA

No. of bags per minute	32



For calculation purposes, we can consider the bag as a simple cylinder although when filled with product, it will form a much flatter shape.

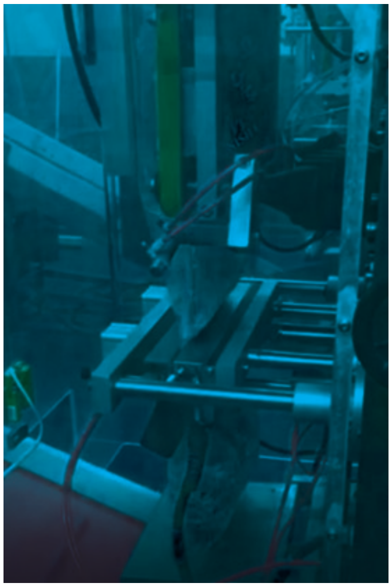
Bag Diameter (mm)	102		1
Bag Length (mm)	320	allowing 15mm either end for crimping	2
Bag volume (litres)	2.61		3

Typically, use **2 times the bag volume** to calculate gas requirement.

Gas volume per bag	5.21	litres of nitrogen
and packaging at	32	bags per minute
gives a nitrogen flow of	167	litres/min
or	10.0	Nm3/hr

So, the nitrogen generator should be sized to deliver a flowrate of 10.0 Nm3/hr

Excel based calculator devised by Parker to approximate flushing gas requirements.



2.5kg packs of grated cheese MAP on VFFS machine.

Horizontal, form, fill and seal, (HFFS)

HFFS machines, sometimes referred to as “flow wrappers”, operate essentially on the same principal as the VFFS but are used for products that would be difficult to drop vertically into the pack. They are used for products such as, naan breads, pita breads, cakes, fruit and vegetables in open top boxes etc.

As the packaging film forms a tunnel that the produce enters, a snorkel type tube or lance, provides a flow of nitrogen gas to flush the pack.

Pack sizes can be larger on HFFS compared to VFFS, increasing the gas demand, typically up to 30-40 m3/h (66-88 scfm) per machine in some instances.

Flow adjustment and flow meters are often incorporated, as for VFFS machines, and are extremely useful for determining gas usage.

HFFS, (Flow wrapper packaging bakery products).

Tray sealers and vacuum formers

Tray sealers use pre-made containers with an open top that are flushed and then sealed with a film “lid”. Typically, the containers or trays are plastic.

Vacuum formers produce the trays within the machine from a roll of thermoplastic, rather than using pre-made trays.

The trays once filled with product can be flushed with gas before the lid is sealed on or the ambient atmosphere surrounding the product in the tray can be vacuumed out and the MAP gas injected into the pack to relieve the vacuum.

Vacuum, flush and fill is probably the most economical method of MAP for tray sealers because the volume of gas used for each tray, can be approximated as the tray volume minus the product volume. These machines range from single tray hand operated to multiple tray fully automated.

A method to estimate the volume of gas used per pack for vacuum , flush and seal machines would be to calculate the internal volume of the tray – width x length x height minus the volume of the food product within the tray.

Other Products Produced on MAP Machines

Milk, coffee and other powdered products can also be packaged on a tin filling and flushing machine as an alternative to bags.

Coffee pods, discs and capsules can be produced on a specialist pod packing machine. Generally, these products are packaged in a foil type barrier film.

Gas flushed, “microwave in the bag” rice, produced using a pouch filling machine.

Typical Gas Mixes by Food Product

Gas Mixes

Dried Foods

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Beans - dried	100	0	0	100	0	0	0.5
Cereals	100	0	0	100	0	0	0.5
Cocoa Powder	100	0	0	100	0	0	0.5 - 0.1
Coffee	100	0	0	100	0	0	0.5 - 0.1
Colorings - dried	100	0	0	100	0	0	0.5
Fish - dried & salted	100	0	0	100	0	0	0.5
Flavorings - dried	100	0	0	100	0	0	0.5
Flours	100	0	0	100	0	0	0.5
Fruits - dried	100	0	0	100	0	0	0.5
Herbs - dried	100	0	0	100	0	0	0.5
Lentils - dried	100	0	0	100	0	0	0.5
Milk Powder	100	0	0	100	0	0	0.5 - 0.1
Mushrooms - dried	100	0	0	100	0	0	0.5
Nuts	100	0	0	100	0	0	0.5
Pasta - dried	100	0	0	100	0	0	0.5
Potato Chips	100	0	0	100	0	0	0.5
Sea Food - dried & salted	100	0	0	100	0	0	0.5
Spices - dried	100	0	0	100	0	0	0.5
Tea	100	0	0	100	0	0	0.5
Vegetables - dried	100	0	0	100	0	0	0.5

Cheese and Dairy

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Cheese block - Excluding Mold Ripened	80	0	20	0	0	1	0.1 - 0.5
Sliced Cheese - Excluding Mold Ripened	70	0	30	70	0	30	0.1 - 0.5
Grated Cheese - Excluding Mold Ripened	100	0	0	70	0	30	0.1 - 0.5
Butter	100	0	0	100	0	0	0.5
Butter Milk	100	0	0	100	0	0	0.1
Cream Cakes	100	0	0	100	0	0	0.1 - 0.5
Custards	100	0	0	100	0	0	0.1 - 0.5
Margerine	100	0	0	100	0	0	0.5
Yogurts	100	0	0	100	0	0	0.1 - 0.5
Yogurts Fruit Puree	100	0	0	100	0	0	0.5

Fresh Fruit & Vegetables

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Apples	90	5	5	90	5	5	0.5 - 1.0
Apricots	90	5	5	90	5	5	0.5 - 1.0
Artichoke	90	5	5	90	5	5	0.5 - 1.0
Aubergine	90	5	5	90	5	5	0.5 - 1.0
Avacado	90	5	5	90	5	5	0.5 - 1.0
Bananas	90	5	5	90	5	5	0.5 - 1.0
Bean Sprouts	90	5	5	90	5	5	0.5 - 1.0
Beetroot	90	5	5	90	5	5	0.5 - 1.0
Beans	90	5	5	90	5	5	0.5 - 1.0
Broccoli	90	5	5	90	5	5	0.5 - 1.0
Cabbages	90	5	5	90	5	5	0.5 - 1.0
Carrots	90	5	5	90	5	5	0.5 - 1.0
Celery	90	5	5	90	5	5	0.5 - 1.0
Cucumber	90	5	5	90	5	5	0.5 - 1.0
Cumquats	90	5	5	90	5	5	0.5 - 1.0
Fennel	90	5	5	90	5	5	0.5 - 1.0
Garlic	90	5	5	90	5	5	0.5 - 1.0
Citrus Fruits	90	5	5	90	5	5	0.5 - 1.0
Grapes	90	5	5	90	5	5	0.5 - 1.0
Guava	90	5	5	90	5	5	0.5 - 1.0
Kiwi Fruit	90	5	5	90	5	5	0.5 - 1.0
Leek	90	5	5	90	5	5	0.5 - 1.0
Lettuce	90	5	5	90	5	5	0.5 - 1.0
Lychees	90	5	5	90	5	5	0.5 - 1.0
Mango	90	5	5	90	5	5	0.5 - 1.0
Marrow	90	5	5	90	5	5	0.5 - 1.0
Melons	90	5	5	90	5	5	0.5 - 1.0
Mixed Salads	90	5	5	90	5	5	0.5 - 1.0
Okra	90	5	5	90	5	5	0.5 - 1.0
Onions	90	5	5	90	5	5	0.5 - 1.0
Sprouts	90	5	5	90	5	5	0.5 - 1.0
Papayas	90	5	5	90	5	5	0.5 - 1.0
Parsnips	90	5	5	90	5	5	0.5 - 1.0
Passion Fruit	90	5	5	90	5	5	0.5 - 1.0
Peaches	90	5	5	90	5	5	0.5 - 1.0
Pears	90	5	5	90	5	5	0.5 - 1.0
Peas	90	5	5	90	5	5	0.5 - 1.0
Peppers	90	5	5	90	5	5	0.5 - 1.0
Pineapple	90	5	5	90	5	5	0.5 - 1.0
Plums	90	5	5	90	5	5	0.5 - 1.0
Potatoes	90	5	5	90	5	5	0.5 - 1.0
Radish	90	5	5	90	5	5	0.5 - 1.0
Rhubarb	90	5	5	90	5	5	0.5 - 1.0
Spinach	90	5	5	90	5	5	0.5 - 1.0
Strawberries	90	5	5	90	5	5	0.5 - 1.0
Sweetcorn	90	5	5	90	5	5	0.5 - 1.0
Tomatoes	90	5	5	90	5	5	0.5 - 1.0
Berries - Other	90	5	5	90	5	5	0.5 - 1.0

Cooked and Dressed Vegetables

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Chilli Beans	70	0	30	50	0	50	0.1 - 0.5
Cooked Beans	70	0	30	50	0	50	0.1 - 0.5
Cooked Potatoes	70	0	30	50	0	50	0.1 - 0.5
Corn Fritters	70	0	30	50	0	50	0.1 - 0.5
Garlic Mushrooms	70	0	30	50	0	50	0.1 - 0.5
Onion Bhajis	70	0	30	50	0	50	0.1 - 0.5
Other dressed Salads	70	0	30	50	0	50	0.1 - 0.5
Pakoras	70	0	30	50	0	50	0.1 - 0.5
Pasta & Potato Salad	70	0	30	50	0	50	0.1 - 0.5
Quorn products	70	0	30	50	0	50	0.1 - 0.5
Rice Salads	70	0	30	50	0	50	0.1 - 0.5
Rissoles	70	0	30	50	0	50	0.1 - 0.5
Stuffed Mushrooms	70	0	30	50	0	50	0.1 - 0.5
Stuffed Peppers	70	0	30	50	0	50	0.1 - 0.5
Stuffed Tomatoes	70	0	30	50	0	50	0.1 - 0.5
Veg with Cheese Sauce	70	0	30	50	0	50	0.1 - 0.5
Vegetable Bakes	70	0	30	50	0	50	0.1 - 0.5
Vegetable Currys	70	0	30	50	0	50	0.1 - 0.5
Vegetable Flans	70	0	30	50	0	50	0.1 - 0.5
Vegetable Pastas	70	0	30	50	0	50	0.1 - 0.5
Vegetable Pies	70	0	30	50	0	50	0.1 - 0.5
Vegetable Rices	70	0	30	50	0	50	0.1 - 0.5
Vegetarian Burgers	70	0	30	50	0	50	0.1 - 0.5

Cooked Meat

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Bacon	70	0	30	50	0	50	500ppm - 0.5%
Beefburgers	70	0	30	50	0	50	500ppm - 0.5%
Black Pudding	70	0	30	50	0	50	500ppm - 0.5%
Charcuterie	70	0	30	50	0	50	500ppm - 0.5%
Frankfurters	70	0	30	50	0	50	500ppm - 0.5%
Ham	70	0	30	50	0	50	500ppm - 0.5%
Meat Jerky	70	0	30	50	0	50	500ppm - 0.5%
Ox Tongue	70	0	30	50	0	50	500ppm - 0.5%
Pastrami	70	0	30	50	0	50	500ppm - 0.5%
Pepperoni	70	0	30	50	0	50	500ppm - 0.5%
Roast meats	70	0	30	50	0	50	500ppm - 0.5%
Salami	70	0	30	50	0	50	500ppm - 0.5%
Sausages	70	0	30	50	0	50	500ppm - 0.5%
Sliced Meats	70	0	30	50	0	50	500ppm - 0.5%
Smoked Meats	70	0	30	50	0	50	500ppm - 0.5%
Wurst	70	0	30	50	0	50	500ppm - 0.5%

Raw Meat

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Goat	0	70	30	0	65	35	N/A
Hare	0	70	30	0	65	35	N/A
Horse	0	70	30	0	65	35	N/A
Lamb	0	70	30	0	65	35	N/A
Pork	0	70	30	0	80	20	N/A
Rabbit	0	70	30	0	65	35	N/A
Veal	0	70	30	0	65	35	N/A
Venison	0	80	20	0	80	20	N/A
Wild Boar	0	80	20	0	80	20	N/A
Giblets	0	80	20	0	80	20	N/A
Heart	0	80	20	0	80	20	N/A
Kidney	0	80	20	0	80	20	N/A
Liver	0	80	20	0	80	20	N/A
Neck	0	80	20	0	80	20	N/A
Oxtail	0	80	20	0	80	20	N/A
Pate - Foie Gras	0	80	20	0	80	20	N/A
Sweetbread	0	80	20	0	80	20	N/A
Tounge	0	80	20	0	80	20	N/A
Tripe	0	80	20	0	80	20	N/A
Capon	70	0	30	0	0	100	0.10
Chicken	70	0	30	0	0	100	0.10
Dark Poultry Mince	0	70	30	0	70	30	N/A
Dark Poultry Sliced	0	70	30	0	70	30	N/A
Duck	70	0	30	0	0	100	0.10
Goose	70	0	30	0	0	100	0.10
Grouse	70	0	30	0	0	100	0.10
Guinea Fowl	70	0	30	0	0	100	0.10
Pheasant	70	0	30	0	0	100	0.10
Poussin	70	0	30	0	0	100	0.10
Quail	70	0	30	0	0	100	0.10
Skin-Off Poultry	0	70	30	0	70	30	N/A
Turkey	70	0	30	0	0	100	0.10

Raw Fish & Shellfish

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Abalone	30	30	40	30	0	70	0.1 -0.5
Bluefish	60	0	40	30	0	70	0.1-0.5
Bream	30	30	40	30	0	70	0.5 - 1.0
Carp	60	0	40	30	0	70	0.1-0.5
Catfish	30	30	40	30	0	70	0.5 - 1.0
Clams	30	30	40	30	0	70	0.1 -0.5
Cockles	30	30	40	30	0	70	0.1 -0.5
Cod	30	30	40	30	0	70	0.5 - 1.0
Conch	30	30	40	30	0	70	0.1 -0.5
Crab	30	30	40	30	0	70	0.1 -0.5
Crayfish	30	30	40	30	0	70	0.1 -0.5
Cuttlefish	30	30	40	30	0	70	0.1 -0.5
Dab	30	30	40	30	0	70	0.5 - 1.0
Eel	60	0	40	30	0	70	0.1-0.5
Flounder	30	30	40	30	0	70	0.5 - 1.0
Greenland Halibut	60	0	40	30	0	70	0.1-0.5
Grouper	30	30	40	30	0	70	0.5 - 1.0
Haddock	30	30	40	30	0	70	0.5 - 1.0
Herring	60	0	40	30	0	70	0.1-0.5
Hoki	30	30	40	30	0	70	0.5 - 1.0
Huss / Dog Fish	30	30	40	30	0	70	0.5 - 1.0
John Dory	30	30	40	30	0	70	0.5 - 1.0
Lobster	30	30	40	30	0	70	0.1 -0.5
Mackerel	60	0	40	30	0	70	0.1-0.5
Monkfish	30	30	40	30	0	70	0.5 - 1.0
Mussels	30	30	40	30	0	70	0.1 -0.5
Octopus	30	30	40	30	0	70	0.1 -0.5
Oysters	30	30	40	30	0	70	0.1 -0.5
Pike	30	30	40	30	0	70	0.5 - 1.0
Pilchard	60	0	40	30	0	70	0.1-0.5
Plaice	30	30	40	30	0	70	0.5 - 1.0
Pollack	30	30	40	30	0	70	0.5 - 1.0
Prawns	30	30	40	30	0	70	0.1 -0.5
Red Snapper	30	30	40	30	0	70	0.5 - 1.0
Salmon	60	0	40	30	0	70	0.1-0.5
Sardine	60	0	40	30	0	70	0.1-0.5
Sea Bass	30	30	40	30	0	70	0.5 - 1.0
Shark	30	30	40	30	0	70	0.5 - 1.0
Shrimp	30	30	40	30	0	70	0.1 -0.5
Skate / Ray	30	30	40	30	0	70	0.5 - 1.0
Sole	30	30	40	30	0	70	0.5 - 1.0
Squid	30	30	40	30	0	70	0.1 -0.5
Swordfish	60	0	40	30	0	70	0.1-0.5
Trout	60	0	40	30	0	70	0.1-0.5
Tuna	60	0	40	30	0	70	0.1-0.5
Turbot	30	30	40	30	0	70	0.5 - 1.0
Whelks	30	30	40	30	0	70	0.1 -0.5
Whitebait	60	0	40	30	0	70	0.1-0.5
Whiting	30	30	40	30	0	70	0.5 - 1.0
Winkles	30	30	40	30	0	70	0.1 -0.5

Cooked Fish & Shellfish

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Bloaters (Smoked Herring)	70	0	30	30	0	70	0.1 - 0.5
Bombay Duck	70	0	30	30	0	70	0.1 - 0.5
Cold smoked Fish	70	0	30	30	0	70	0.1 - 0.5
Kippers	70	0	30	30	0	70	0.1 - 0.5
Salt Cod	70	0	30	30	0	70	0.1 - 0.5
Salted Anchovies	70	0	30	30	0	70	0.1 - 0.5
Hot Smoked Fish	70	0	30	30	0	70	0.1 - 0.5
Potted Fish	70	0	30	30	0	70	0.1 - 0.5
Salted Caviar	70	0	30	30	0	70	0.1 - 0.5
Salted Fish Roes	70	0	30	30	0	70	0.1 - 0.5
Taramasalata	70	0	30	30	0	70	0.1 - 0.5
Prawns - Peeled	60	0	40	60	0	40	0.1 - 0.5

Fresh Pasta

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Capelli	50	0	50	50	0	50	0.1 - 0.5
Fettucine	50	0	50	50	0	50	0.1 - 0.5
Funghini	50	0	50	50	0	50	0.1 - 0.5
Fusilli	50	0	50	50	0	50	0.1 - 0.5
Linguine	50	0	50	50	0	50	0.1 - 0.5
Macaroni	50	0	50	50	0	50	0.1 - 0.5
Pasta Shells	50	0	50	50	0	50	0.1 - 0.5
Spaghetti	50	0	50	50	0	50	0.1 - 0.5
Tagliarini	50	0	50	50	0	50	0.1 - 0.5
Tagliatelle	50	0	50	50	0	50	0.1 - 0.5
Trenette	50	0	50	50	0	50	0.1 - 0.5
Tubetti	50	0	50	50	0	50	0.1 - 0.5
Vermicelli	50	0	50	50	0	50	0.1 - 0.5
Zitioni	50	0	50	50	0	50	0.1 - 0.5

Convenience Foods

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Battered / Breaded Fish	70	0	30	50	0	50	0.1 - 0.5
Battered / Breaded Seafood	70	0	30	50	0	50	0.1 - 0.5
Battered / Breaded Meat	70	0	30	50	0	50	0.1 - 0.5
Battered / Breaded Poultry	70	0	30	50	0	50	0.1 - 0.5
Burritos	70	0	30	50	0	50	0.1 - 0.5
Crepes / Pancakes - Filled	70	0	30	50	0	50	0.1 - 0.5
Enchiladas	70	0	30	50	0	50	0.1 - 0.5
Falafel	70	0	30	50	0	50	0.1 - 0.5
Kebabs	70	0	30	50	0	50	0.1 - 0.5
Omlettes / Tortillas	70	0	30	50	0	50	0.1 - 0.5
Pasties	70	0	30	50	0	50	0.1 - 0.5
Pizzas	70	0	30	50	0	50	0.1 - 0.5
Pasta containing Meat	70	0	30	50	0	50	0.1 - 0.5
Pasta containing Fish / Seafood	70	0	30	50	0	50	0.1 - 0.5
Pasta containing Poultry	70	0	30	50	0	50	0.1 - 0.5
Pies containing Meat	70	0	30	50	0	50	0.1 - 0.5
Pies containing Fish / Seafood	70	0	30	50	0	50	0.1 - 0.5
Pies containing Poultry	70	0	30	50	0	50	0.1 - 0.5
Quiche	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Fish	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Game	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Meat	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Offal	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Goulash	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Poultry	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Pasta	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Seafood	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Vegetables	70	0	30	50	0	50	0.1 - 0.5
Ready Meal Containing Soup	70	0	30	50	0	50	0.1 - 0.5
Sandwiches	70	0	30	50	0	50	0.1 - 0.5
Satay	70	0	30	50	0	50	0.1 - 0.5
Sausage Rolls	70	0	30	50	0	50	0.1 - 0.5
Spring Rolls	70	0	30	50	0	50	0.1 - 0.5
Stuffed Pitta Bread	70	0	30	50	0	50	0.1 - 0.5
Tacos	70	0	30	50	0	50	0.1 - 0.5
Tostadas	70	0	30	50	0	50	0.1 - 0.5
Vol au Vonts	70	0	30	50	0	50	0.1 - 0.5

Convenience Foods

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Bagels	50	0	50	30	0	70	0.1 - 0.5
Bread Based Desserts	50	0	50	30	0	70	0.1 - 0.5
Buns	50	0	50	30	0	70	0.1 - 0.5
Cheesecake	50	0	50	30	0	70	0.1 - 0.5
Crepes - Unfilled	50	0	50	30	0	70	0.1 - 0.5
Croissants	50	0	50	30	0	70	0.1 - 0.5
Crumpets	50	0	50	30	0	70	0.1 - 0.5
Danish Pasteries	50	0	50	30	0	70	0.1 - 0.5
Fruit Bread	50	0	50	30	0	70	0.1 - 0.5
Fruit Cake	50	0	50	30	0	70	0.1 - 0.5
Fruit Pies	50	0	50	30	0	70	0.1 - 0.5
Strudel	50	0	50	30	0	70	0.1 - 0.5
Fruit Tarts	50	0	50	30	0	70	0.1 - 0.5
Meringues	50	0	50	30	0	70	0.1 - 0.5
Muffins	50	0	50	30	0	70	0.1 - 0.5
Naan Bread	50	0	50	30	0	70	0.1 - 0.5
Nut Bread	50	0	50	30	0	70	0.1 - 0.5
Pitta Bread	50	0	50	30	0	70	0.1 - 0.5
Pizza Bases	50	0	50	30	0	70	0.1 - 0.5
Pretzels	50	0	50	30	0	70	0.1 - 0.5
Sponge Cakes	50	0	50	30	0	70	0.1 - 0.5
Swiss Roll	50	0	50	30	0	70	0.1 - 0.5
Taco Shells - Unfilled	50	0	50	30	0	70	0.1 - 0.5
Vegetable Breads	50	0	50	30	0	70	0.1 - 0.5
Waffles	50	0	50	30	0	70	0.1 - 0.5

Beverages

Product	Retail Pack % v			Bulk Pack % v			N_2 Generator MROC %
	N_2	O_2	CO_2	N_2	O_2	CO_2	
Beer	100	0	0	100	0	0	0.1 - 0.5
Fruit Juice	100	0	0	100	0	0	0.5
Liqueurs	100	0	0	100	0	0	0.5
Yogurt Drink	100	0	0	100	0	0	0.5
Milk	100	0	0	100	0	0	0.5
Mineral Water	100	0	0	100	0	0	0.5
Spirits	100	0	0	100	0	0	0.5
Vegetable Juice	100	0	0	100	0	0	0.5
Wine	100	0	0	100	0	0	0.5

The tables printed within this publication are a combination of multiple sources of data obtained from research within the public domain. They represent a guide only and are not definitive in their suitability for the food products indicated.

While modified atmosphere packaging helps to extend the shelf life, as well as enhance the flavour and appearance of food products, it is not a substitute for hygienic, good manufacturing practices and correct food storage temperatures.

Worldwide Filtration Manufacturing Locations

North America

Compressed Air Treatment

Industrial Gas Filtration and Generation Division
Lancaster, NY
716 686 6400
www.parker.com/igfg

Haverhill, MA
978 858 0505
www.parker.com/igfg

Engine Filtration

Racor
Modesto, CA
209 521 7860
www.parker.com/racor

Holly Springs, MS
662 252 2656
www.parker.com/racor

Hydraulic Filtration

Hydraulic & Fuel Filtration
Metamora, OH
419 644 4311
www.parker.com/hydraulicfilter

Laval, QC Canada
450 629 9594
www.parkerfarr.com

Velcon
Colorado Springs, CO
719 531 5855
www.velcon.com

Process Filtration

domnick hunter Process Filtration SciLog
Oxnard, CA
805 604 3400
www.parker.com/processfiltration

Water Purification

Village Marine, Sea Recovery, Horizon Reverse Osmosis
Carson, CA
310 637 3400
www.parker.com/watermakers

Europe

Compressed Air Treatment

domnick hunter Filtration & Separation
Gateshead, England
+44 (0) 191 402 9000
www.parker.com/dhfns

Parker Gas Separations
Etten-Leur, Netherlands
+31 76 508 5300
www.parker.com/dhfns

Hiross Zander
Essen, Germany
+49 2054 9340
www.parker.com/hzfd

Padova, Italy
+39 049 9712 111
www.parker.com/hzfd

Engine Filtration & Water Purification

Racor
Dewsbury, England
+44 (0) 1924 487 000
www.parker.com/rfde

Racor Research & Development
Stuttgart, Germany
+49 (0)711 7071 290-10

Hydraulic Filtration

Hydraulic Filter
Arnhem, Holland
+31 26 3760376
www.parker.com/hfde

Urjala, Finland
+358 20 753 2500

Condition Monitoring Parker Kittiwake
West Sussex, England
+44 (0) 1903 731 470
www.kittiwake.com

Process Filtration

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Birtley, England
+44 (0) 191 410 5121
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www.parker.com/india

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+91 80 2783 6794
www.johnfowlerindia.com

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Bangkok, Thailand
+66 2186 7000
www.parker.com/thailand

Latin America

Parker Comercio Ltda. Filtration Division
Sao Paulo, Brazil
+55 12 4009 3500
www.parker.com/br

Pan American Division
Miami, FL
305 470 8800
www.parker.com/panam

Africa

Aeroport Kempton Park, South Africa
+27 11 9610700
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