APPLICATION BROCHURE

APPLICATION SHOWCASE

Reverse Osmosis and Ultrafiltration

Partial view of Wester Ross, Scotland, home to one of our Fyne Process sites.

PCI Membranes Filtration Group®

INTRODUCTION TO REVERSE OSMOSIS

Osmosis is a natural occurring process. When two liquids of different concentrations are separated by a semi permeable membrane, the fluid has a tendency to move from low to high solute concentrations for chemical potential equilibrium.

Reverse Osmosis (RO) is a membrane filtration method that removes many types of large molecules and ions from solutions by applying pressure to the solution when it is on one side of a selective membrane. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side.

Formally, RO is the process of forcing a solvent from a region of high solute concentration through a semi permeable membrane to a region of low solute concentration by applying a pressure in excess of the osmotic pressure. The products and applications detailed in the following section, all utilise our membrane technology in the RO process.

B1 SERIES

The tubular B1 module provides the user with a robust, proven, Microfiltration, Ultrafiltration, Nanofiltration, and Reverse Osmosis module and a wide range of fully interchangeable membrane elements.

Each module, up to 3.6m long, comprises 18 perforated stainless steel tubes in the form of a shell and tube, each tube is fitted with a membrane element. The shell, or shroud, is also fabricated from stainless steel and has outlets fitted for the permeate, the liquid that passes through the membrane.

Flow of the process fluid through the tubes is effected by specially designed end-caps whose design varies depending on the process requirements.

- **Series Flow**
- **Twin Entry Flow**
- **Parallel Flow**

Manufactured with materials approved by FDA, CFR21 and EU regulations.

Dimensions			
Length (m)	1.22	2.44	3.66
Membrane Area (m^2)	0.88	1.75	2.63

Additional Details	
Operating Pressure	Up to 64 bar (80 bar available on request)
Operating Temperature	Up to 80°C
Shroud Material	AISI 316 Stainless Steel
Membrane Type	Suitable for MF, UF, NF & RO Membranes

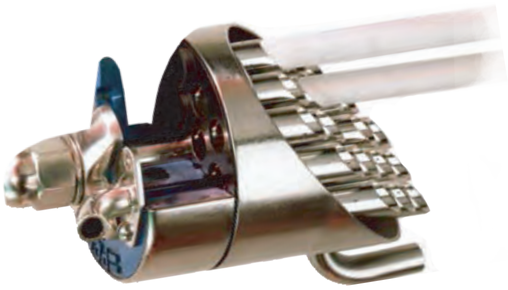
Stainless steel construction
Robust and inert to most chemicals.

Proven Membranes
With applications in the food, beverage, chemical, industrial and pharmaceutical industries.

Compact Module Design
Quick and easy plant construction.

Open channel, tubular design
Minimal feed prefiltration required; suitable for high levels of suspended solids: Maximum effectiveness of CIP

Choice of flow path through module
Optimum cross-flow velocities to minimise fouling with acceptable pressure drop.



SERIES FLOW

Configuration

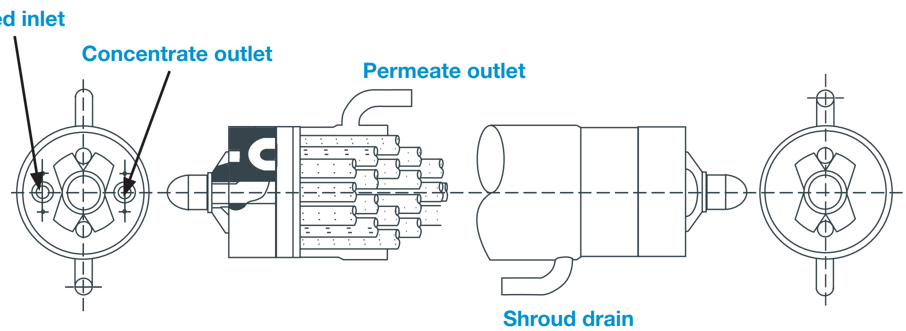
Each Reverse Osmosis module comprises 18 perforated stainless steel tubes in the form of a shell and tube, each tube is fitted with a membrane element. Flow of the process fluid through each of the tubes is effected by specially designed end caps connecting all eighteen tubes in series. For viscous materials an alternative end cap arrangement is available which allows the overall pressure drop to be minimised.

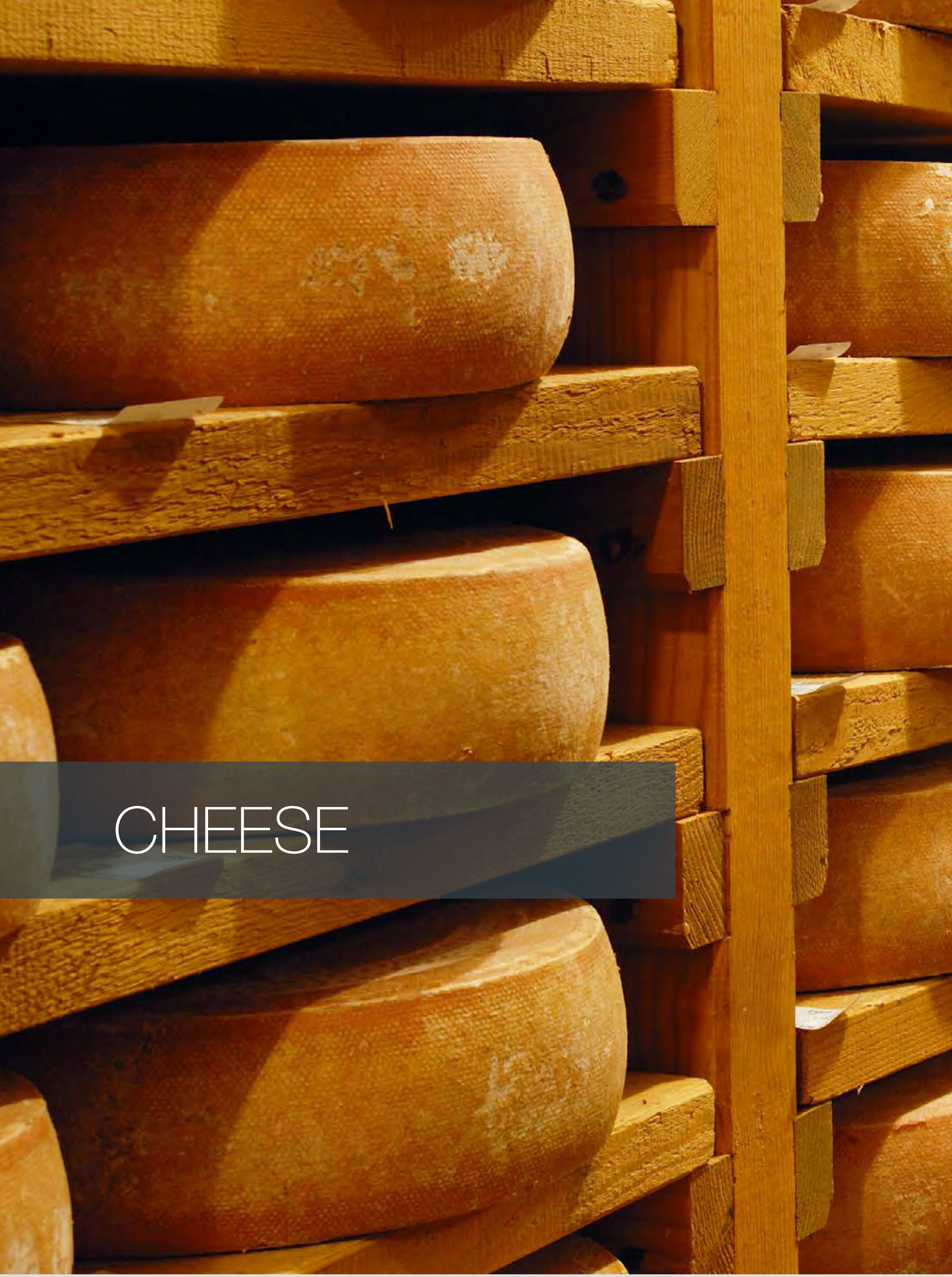
The open channel, highly turbulent flow design allows a wide variety of process liquors to be concentrated, with minimal pretreatment. High levels of suspended materials can be tolerated. The design is free of dead spaces, which reduces the fouling potential of the membranes while ensuring maximum effectiveness of cleaning.

Module Length (M)	Membrane Area (M^2)	Weight Empty (kg)	Hold-up Volume Tube-side (Ltrs)	Hold-up Volume Shroud-side (Ltrs)	Membrane Tube ID. (mm)
1.22	0.88	15.0	2.8	6.7	12.7
2.44	1.75	24.7	5.6	13.3	12.7
3.66	2.63	34.5	8.4	20.0	12.7

Connections	
Permeate	12.7mm OD for flexible hose
Feed	For 12.7mm oval flange

Tube-Side Mechanical Operating Limits	
Operating Pressure	Up to 64 bar (80 bar available on request)
Pressure Drop	10 bar max
Operating Temperature	Up to 80°C
Shroud Material	AISI 316 Stainless Steel
Membrane Type	Suitable for MF, UF, NF & RO Membranes



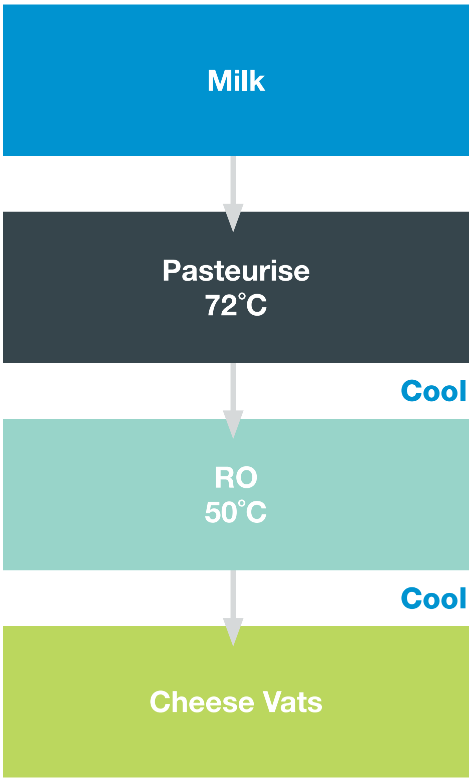


CHEESE

CHEESE PROCESSING

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquid Characteristics: Whole or Skimmed Milk

PCI Experience/Status

- Lab. PCI BRO/BUF -Y
- On Site trials BRO/MSR -Y
- Reference Plant -Y

Trial Location/Ref No.

- Americas
- 4326 Ireland
- Reference Plant ROP 1006 & 1315

Budget Design Data	
Flux range	20-25 l/m²/h
Max concentrations	x2 Depends on cheese type
Temperature	50-55 °C
Pressure	30-50 bar
Permeate Characteristics	BOD 100 Guaranteed
Actual	**30 - 50 mg/l**

Key Technical Factors

1. Max 1.2 to 1.25 VCF for Cheddar/hard cheese.
2. Homogenisation of fat may require capillary pressure control, especially if not pasteurised.
3. Different considerations for alternative cheeses. PCI has experience with Cheddar, Cottage cheese.
4. Adjustments to cheese making process would be required to maintain a standard product.

Key Commercial Factors

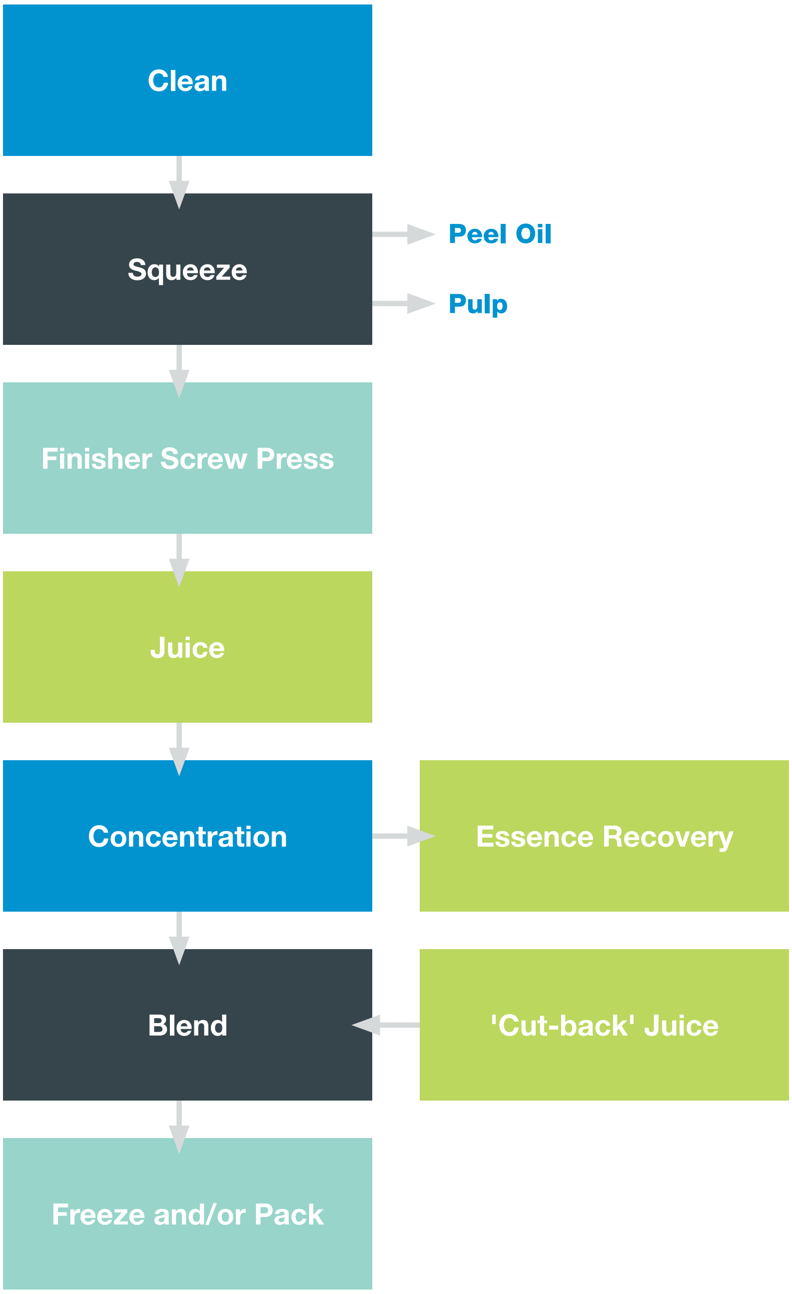
1. 1-3% yield increase hard cheese, higher for soft cheese 20-30% less starter. Payback less than 1 year.
2. Same benefits by evaporators.
3. Legal Acceptability.

ORANGE JUICE

ORANGE JUICE

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- Viscosity = 7 - 15 cp for 10° - 25° Brix at 20° - 23°C. Viscosity reduced to 5.5 cp at 43°C.
- pH = 3.5 - 4.0.
- Specific Gravity = 1.03 - 1.10 for 10° - 25° Brix at 20° - 23 °C.

PCI Experience/Status

- Lab. PCI BRO - Y
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location/Ref No.

- Single Module
- Reference Plant ROP 885

Budget Design Data	
Flux range	10 - 15 l/m^2/h
Max concentrations	28° Brix
Temperature	20 °C
Pressure	60 bar
Permeate Characteristics	Not known - retentions likely to be better than apple juice because some volatiles are dispersed in the oil phase

Key Technical Factors

1. Fluxes agree with UCLA (1976) PA300 and Abcor (1980) published figures.
2. We can run at 20°C.
3. Pectin is major potential foulant (Watanane et al, 1980).
4. Limonene is a key component. Limonene is 90% of citrus peel oil.
5. Published data on Limonene recovery attacks Polysulphone, CA, Teflon.
6. Limonene at 16ppm (solubility limit) is OK on soak test.
7. Fouling rate related to oil content (Hesperidin concn.) and the feed flow rate.
8. Hesperidin is a major potential foulant.

Key Commercial Factors

1. Major processing area USA (Florida), Brazil.
2. RO + frozen concentrate - allow low heat, high quality products.
3. High quality product - Food R.A. taste test.

NON-DECANTED TOMATO JUICE

NON-DECANTED TOMATO JUICE

Through Reverse Osmosis

PROCESS DESCRIPTION

Tomatoes

↓

Crushing

↓

Heating — **70-90°C**

↓

Screen — **Removes Pips/Skins**

↓

R.O.

↓

Evaporates

↓

Packaging

- Dissolved solids 4.5 - 5.0° Brix
- Suspended solids 20 - 25% by volume
- Viscosity at 65°C, 8 - 10° Brix = 20 to 300 mPa/S depends upon shear and fibre content

Liquor Characteristics

- Tomato Juice is a Non-Newtonian fluid, which exhibits a plastic flow behavior.
- Density approx 1000 kg/m³
- pH approx 4.5

PCI Experience / Status

- Lab. PCI BRO/BUF - Y
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location / Ref No.

- Reference Plant ROP 0871 & 1680

Budget Design Data	
Flux range	30 - 50 l/m²/h
Max concentrations	8 - 9° Brix
Temperature	60 - 70°C
Pressure	40 - 50 bar
Permeate Characteristics	COD 1200 mg/l

Key Technical Factors

1. Process is limited by fluid viscosity.
2. Problems with blocking of module.
3. Seasonal production with throughput likely to vary with time.
4. Novel operating procedures required to prevent module blockage.
5. Caustic and soap cleaning.
6. No daily sterilisation.
7. A installation is achieving 28° Brix at 64 bar operating pressure.

Key Commercial Factors

1. Reasons - Reduce evaporator size and electricity costs, improving overall operational cost. Resulting in a quality in a cleaner color and taste of the final concentrate.
2. Most evaporators only 2 - 3 times more concentration.
3. Short production periods of 60 - 100 days/year.

NON-DECANTED TOMATO JUICE

Through Reverse Osmosis

Case Study: Agricoltori Riuniti Piacentini (ARP), Italy

Background

ARP has expanded continuously since 1958, when 7000 tonnes of tomatoes were processed, up to 100,000 tonnes/year (1984 figures). The factory produces 28°-30° Brix and 36°-38° Brix concentrate for major European clients.

Previous Process

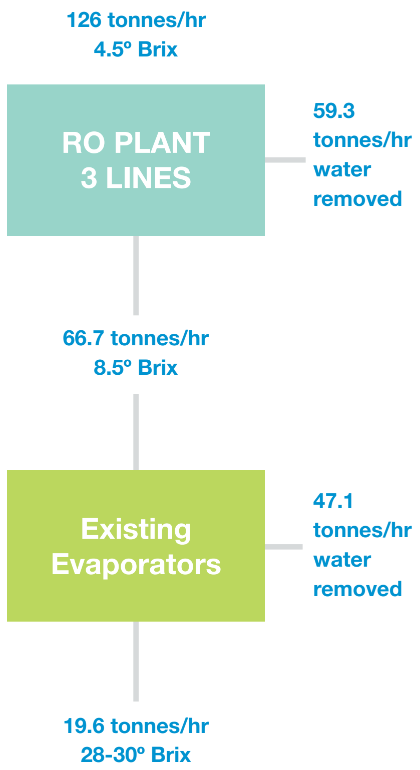
In the 1983 season, the factory process was the standard hot break process with feed juice at an average of 4.5° Brix going to 2 large triple effect evaporators which concentrate 80 tonnes/hr of feed juice directly to concentrate/paste product.

The water removal requirement for 28°-30° Brix product was approximately 67 tonnes/hr, with a steam consumption of approximately 25 tonnes/hr at an operating cost of £500/hr.

New Process

ARP decided to expand production by approximately 50% over a two-year period. Two competitive offers for a third large triple effect evaporator were considered in conjunction with PCI's RO system.

The traditional evaporator scheme would have required additional capital investment in steam boiler capacity, evaporator cooling system and the related civil engineering costs for these three major items. In addition to this, further increases in the already high fuel oil costs would make the evaporation step a major factor in the overall total processing costs for the factory.



1st Season

The first stage of the expansion was carried out by installing the 42 tonnes/hr three stage PCI reverse osmosis plant. The line pre-concentrated to 8.5° Brix, removing nearly 20 tonnes of water per hour, with a total energy consumption of approximately 150kw of electrical power.

The existing evaporators carried out the final concentration to 28°-30° Brix or 36°-38° Brix. The initial expansion with the first RO line increased overall plant capacity by 900 tonnes/day.

2nd Season

Two additional lines were ordered for 1985, to give a total reverse osmosis plant capacity of 126 tonnes/hr. All tomato pulp juice is pre-concentrated to 8.5° Brix prior to the existing evaporators and the overall capacity of the factory was increased by nearly 50%. The overall factory scheme is shown on the previous page.

Operating Costs (1995 figures)		
Existing	3 Effect Evaporators	£3.30/tonne water removed (based on steam cost plus electricity)
PCI	Reverse Osmosis plant	£1.70/tonne water removed (based on steam cost plus electricity)
Saving	Removing 59.3 tonnes/hr of water by RO for 21hr/day - **£1,922 a day**	

The Situation Today

ARP's production has expanded to 150,000 tonnes of process tomatoes a year. New products have been added to their range such as cubed chopped tomatoes and concentrated tomato juice known as 'Passata'.

The number of active farmers around Piacenza forming part of the co-operative has reduced slightly. However, they have embraced the new technologies allowing them to produce higher quality products with cost-effective production methods.

Conclusion

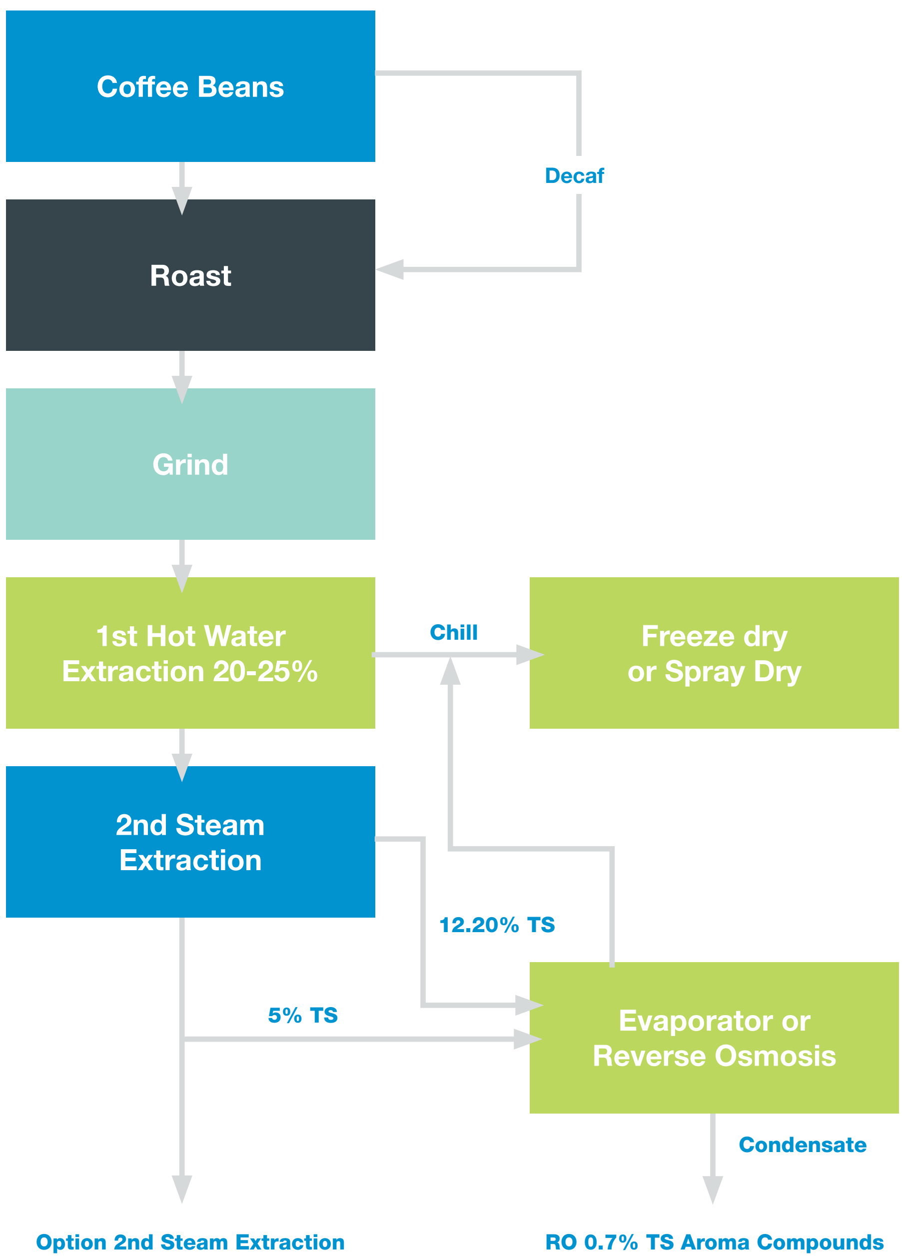
- Increase processing capacity by up to 50%.
- Reduce operating costs by £1,992/day (1995 figures).
- Avoid costly investments in a new evaporator plus the associated new steam, boiler, cooling water system and services.

COFFEE EXTRACT AND AROMA

COFFEE EXTRACT & AROMA

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- 0.5 - 1% TS
- 35000 mg/l COD
- High level suspended solids
- Get full analysis including minerals. Free oils content
- pH about 4

PCI Experience / Status

- Lab. PCI BRO/BUF - Y
- On Site trials BRO - Y

Budget Design Data	
Flux range	10 - 15 l/m²/h
Max concentrations x2	30% TS
Temperature	10 - 30 °C
Pressure	40 - 60 bar
Permeate Characteristics	COD 1200 mg/l

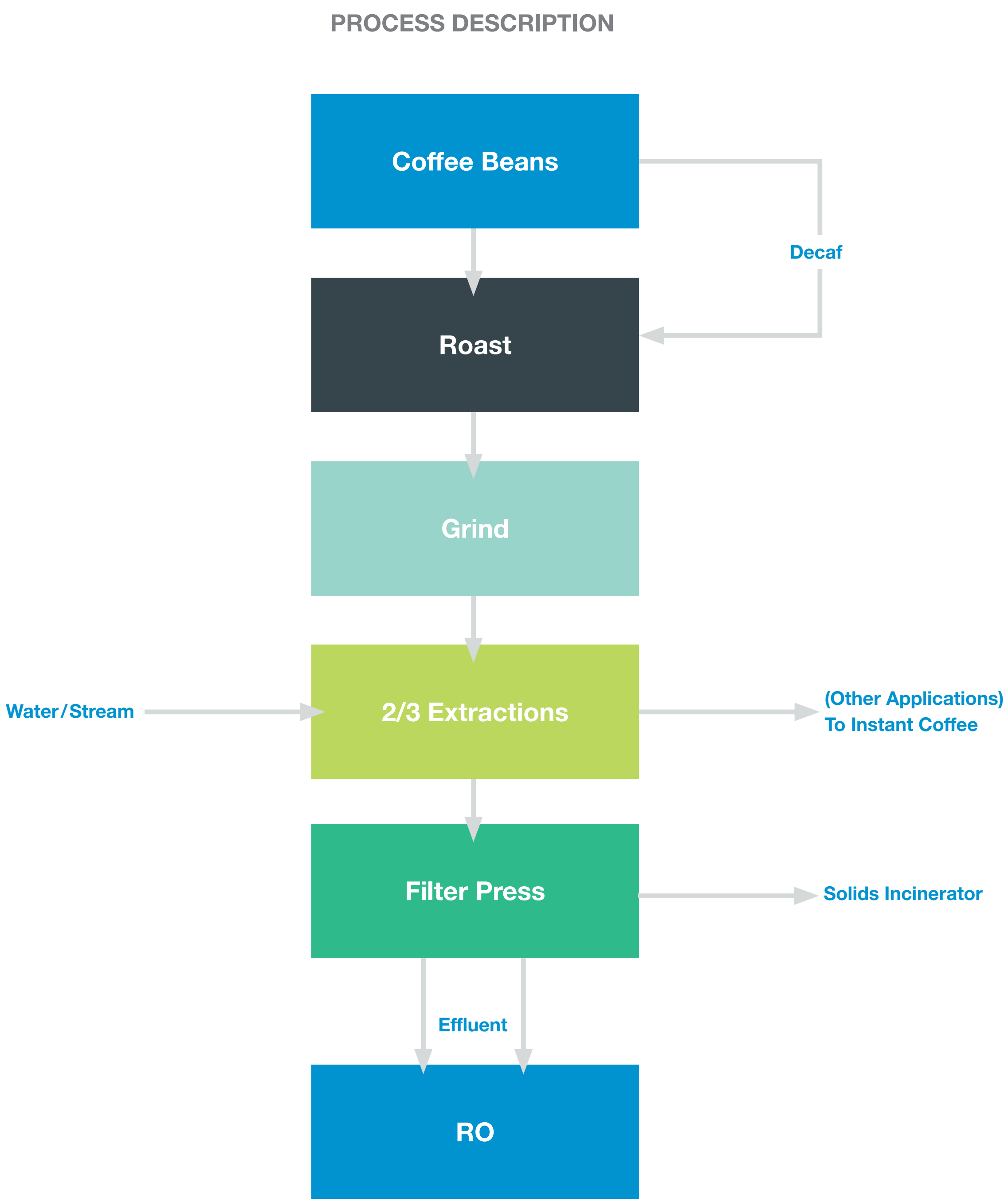
Key Technical Factors

1. Maximum aroma retention required.
2. No long term data yet. Potential AFC99 membrane absorption problem.

COFFEE PRESS LIQUOR

COFFEE PRESS LIQUOR

Through Reverse Osmosis



Liquor Characteristics

- 0.5-1% TS
- 35000 mg/l COD
- pH 4
- High level suspended solids
- Get full analysis including minerals. Free oils content

PCI Experience / Status

- Lab. PCI BRO/BUF - N
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location / Ref No.

- Reference Plant ROP 665

Budget Design Data	
Flux range	20 l/m²/h
Max concentrations x2	15% TS
Temperature	25 - 30 °C
Pressure	40 bar nominal
Permeate Characteristics	COD 1000-3000 mg/l slight colour

Key Technical Factors

1. Upward pH adjustment to avoid formation fatty acid deposits.
2. Prefilter 50 um/free oil skimmed off in settling tanks.
3. AFC99 gives advantage at hight temperature.
4. Weekly cleaning + daily pressure release.

Key Commercial Factors

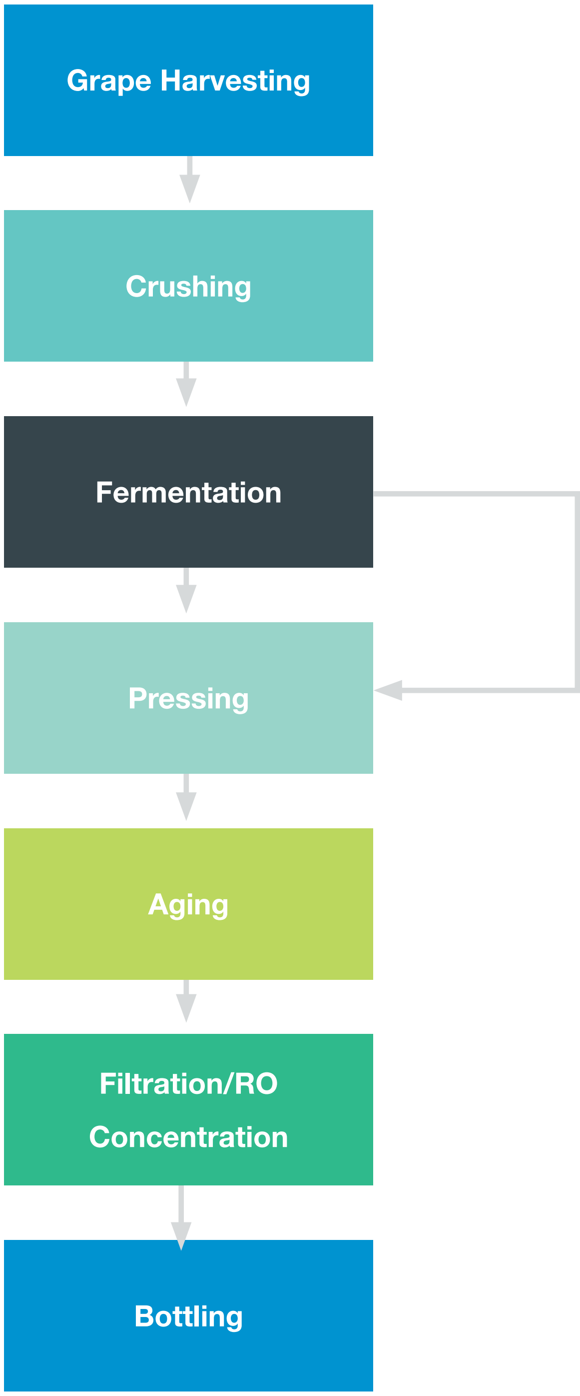
1. E.E.C Regs prohibit re-use of concentrate – Limit of 47.5% coffee extraction.
2. Not easy to evaporate.
3. No known active RO competition (high suspended solids).

CONCENTRATION OF FERMENTED WINE

CONCENTRATION OF FERMENTED WINE

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- Liquor Characteristics: 8 - 10° volume alcohol, pH 3 - 4

PCI Experience/Status

- Lab. PCI BRO/BUF - Y
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location/Ref No.

- Reference Plant France and Italy
- ROP 817

Budget Design Data	
Flux range	10 - 15 l/m²/h
Max concentrations x2	1.5 x VCF from 8.45° alcohol to 10.9° alcohol
Temperature	15 - 20°C
Pressure	55 bar
Permeate Characteristics	Approx 5.5° Volume

Key Technical Factors

1. Alcohol passage in the region of 50 - 75%. This matters less than 'body' or flavour retention. Alcohol can be added back.
2. Small scale batches.

Key Commercial Factors

1. Process substantially upgrades wine quality.
2. Small batch quantities.

GRAPE MUST/JUICE

CONCENTRATION OF GRAPE MUST/JUICE

Through Reverse Osmosis

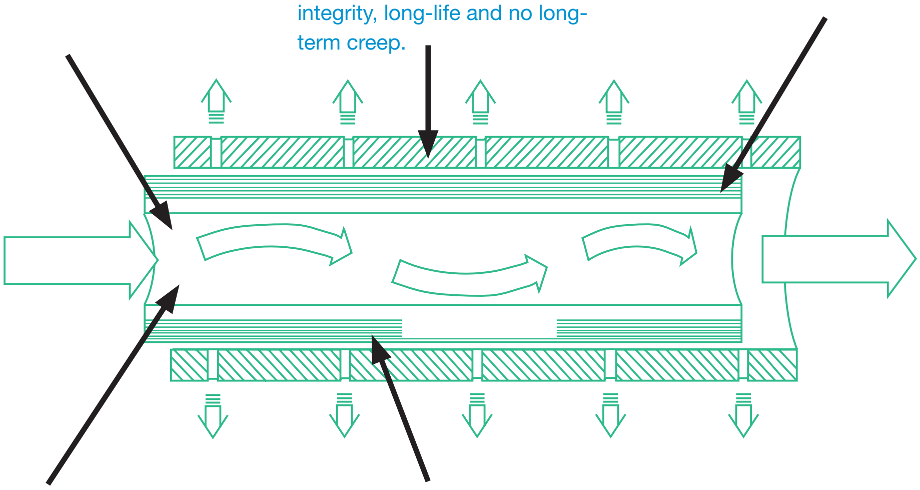
Tubular RO is a process well-suited for the concentration of grape must prior to vinification, since no pre-treatment is required, and very high product quality is realised at economical cost. PCI's RO system uses tubular membranes of 12.7 mm diameter which prevents blockage from occurring without the need for prefiltration of the must. These tubular membranes can be easily and effectively cleaned in place.

High Quality Product

The grape must concentration process operates at ambient temperature thus avoiding losses of volatile aromas and ensuring that the organoleptic qualities of the must are not modified. Red wine must from Cabernet, Merlot and Sauvignon grape varieties can be concentrated by RO up to a sugar content equivalent to 12-13% alcohol.

Potential advantages of concentration by RO

- Concentrated musts are rich in tannin and in organoleptic components.
- Addition of sugar and rectified grape must prior to vinification may not be necessary, and in any case the quantity added is substantially reduced.
- The process does not affect the delicate balance of aromatic compounds in the must, since neither freezing nor evaporation are necessary.



The Reverse Osmosis Process

RO is a non-thermal process consisting of dewatering by the separation of pure water from liquid solutions (such as grape must) by the application of an elevated pressure which causes the water to diffuse through a polymeric membrane. The membrane is impervious to large molecules and retains the valuable components in the must. The process can operate at any temperature between 2°C and 80°C, and since there is no change of phase it is energy efficient. Liquid flow within the system is tangential to the membrane surface thus inhibiting formation of deposits which would reduce processing capacity.

PCI Experience / Status

- Lab. PCI BRO/BUF - Y
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location/Ref No.

- Reference Plant France and Italy
- ROP 817

Process Description

Liquor Characteristics:

- Approx 15° Brix
- pH 3 - 4

Budget Design Data	
Flux range	10 l/m²/h batch
Max concentrations	2x. 22° Brix to 43° Brix
Temperature	15 - 20°C
Pressure	55 bar
Permeate Characteristics	Sugars less than 0.05%, Acidity 3%

Concentration Of Grape Must Data	
Initial Must Volume	170 Lt at 10° (potential alcohol)
Initial Batch Volume	100 Lt at 10°
Water Removed	28 Lt
Concentrated Must	72 Lt at 14.4°
Final Must Volume	142 Lt at 12°
Processing Temp	18 - 20°C
Batch Time	6 hours approx
Membrane Type	AFC99
Membrane Area	70 m²
Overall Dimensions	L=3.7m, W=0.9m, H=2m
Absorbed Power	**26 kW**
Cleaning Procedure	Daily 0.25% Ultrasil 11

Key Technical Factors

1. Small batch scale operations.
2. Final product quality absolutely critical.

Key Commercial Factors

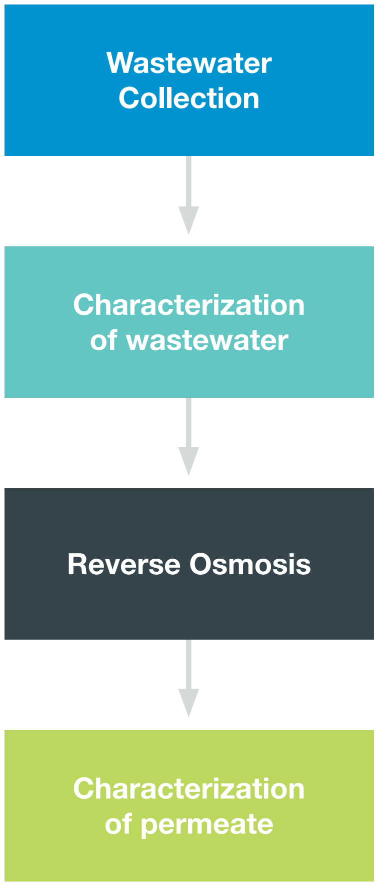
1. Objective is to turn low sugar level juice into superior final products. Perhaps most relevant in the poor growing seasons.
2. Very short processing time, with quick payback period.

YEAST EFFLUENT

YEAST EFFLUENT

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- 1 - 10% TS depending on process and washing steps.
- 2/3rd effluents

PCI Experience/Status

- Lab. PCI BRO/BUF - Y
- On Site trials BRO/MSR - Y
- Reference Plant - Y

Trial Location/Ref No.

- confidential

Budget Design Data	
Flux range	30 l/m²/h batch
Max concentrations x2	10 - 15%
Temperature	50 available normally 20 - 30°C
Pressure	40 - 60 bar
Permeate Characteristics	COD typically 1000 mg/l lower at 30°C

Key Technical Factors

1. Check feedstock - beet or cane.
2. Trials recommended based on feedstock.

Key Commercial Factors

1. Direct competition with evaporators.
2. Suits tubular RO system.

UREA / AMMONIA RECOVERY

UREA/AMMONIA RECOVERY

Through Reverse Osmosis

PROCESS DESCRIPTION

Urea manufacturing by CO_2 and NH_3 by fertiliser producer

Liquor Characteristics

- Approx 2.5% ammonia 3.0%
- Urea pH 10-11

PCI Experience/Status

- Onsite trials BRO/MSR - Y

Budget Design Data	
Flux range	30 l/m²/h
Max concentrations	3% ammonia & 4% Urea
Temperature	50 - 60 °C
Pressure	45 bar
Permeate Characteristics	Approx 2.0% Ammonia Approx 2% Urea

Key Technical Factors

1. Ammonia recovery approx 60%.
2. Urea recovery approx 70%.

Key Commercial Factors

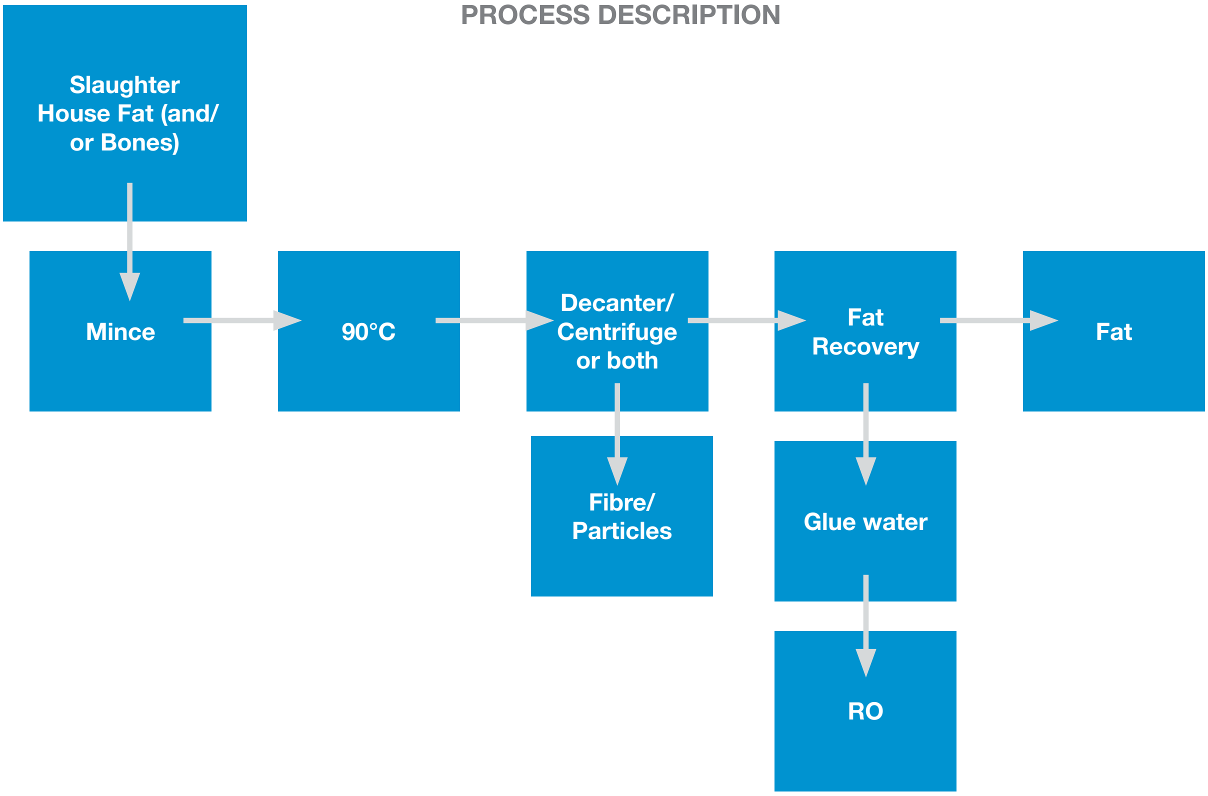
1. Trials represented 50% recovery of urea and ammonia.
2. RO concentrated recoveries are boosted to 70% urea and 60% for ammonia.

GLUEWATER

GLUEWATER

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- 5 - 6% TS (60 Protein, 25 fat, 15 Ash)
- Viscous, solid at 16% ambient temperature.

PCI Experience/Status

- On Site trials BRO/MSR -Y

Trial Location/Ref No.

- Denmark ROQ 4253

Budget Design Data	
Flux range	5-10 l/m²/h
Max concentrations	10 - 20%
Temperature	Approx 70 °C
Pressure	40-60 bar nominal
Permeate Characteristics	BOD expected to be less than 200 mg/l

Key Technical Factors

1. Flux down to 5 l/m²/h, at about 12° Brix.
   Flux down to 2 l/m²/h, at about 16° Brix.
2. Required to get max Brix (normally 16 - 20) for re-use as product i.e. in sausages/luncheon meat.
3. Almost certainly Batch Plant.
4. Very viscous; High Differential Pressure above 10 - 12° Brix.
5. Very variable feed material site/site day/day.
6. Prefiltration/Bone particle removal required.

Key Commercial Factors

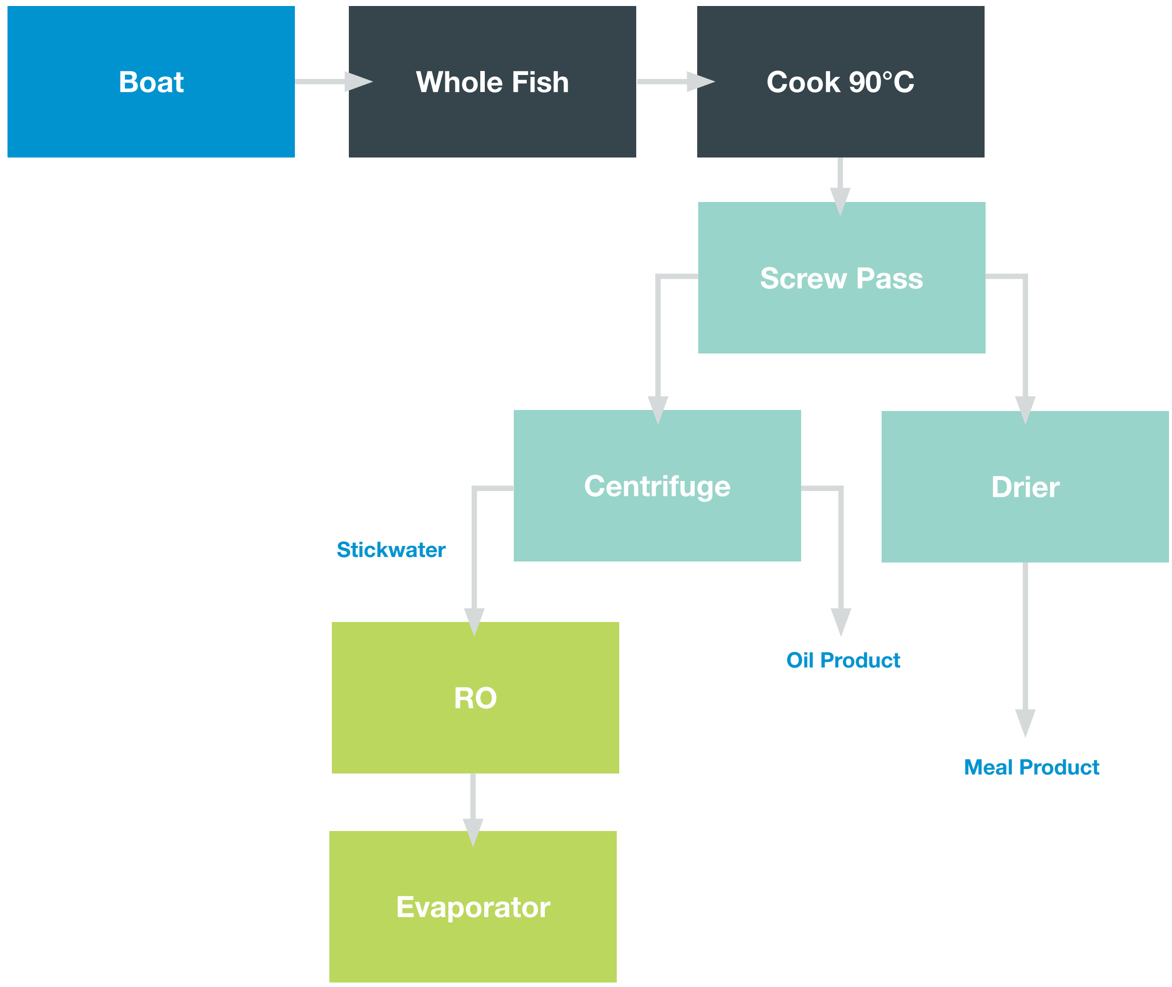
1. Fits well into Alfa Laval meat processing line separators/decanters.
2. Evaporators can work but RO product is better - easier to install.
3. Batch process.
4. Food standards/legislation important (varies can vary by country).

FISH STICK LIQUOR

FISH STICK LIQUOR

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

- Viscosity depends on Pre-filter:

  - at 25% TS 50cP (40µm)
  - at 25% TS 200 cP (100 (100µm)
  - variable, but around 7.5% of which 50 - 75% protein, 10 - 15% fat, 15 - 25% ash
  - Depends on fish type
  - Abrasive (bone particles)
  - pH 7.0 but may be acidified for storage (3.5)

PCI Experience/Status

- Lab. PCI BRO -Y
- On Site trials BRO/MSR -Y
- Reference Plant -Y

Trial Location/Ref No.

- (ROQ) USA
- (no longer in use)
- Norway ROQ 4319

Budget Design Data	
Flux range	15-20 $l/m^2/h$
Max concentrations	15 - 25%
Temperature	60 - 70°C
Pressure	40 - 50 bar
Permeate Characteristics	- BOD/COD not usually critical - Limited TS Data. Less than 0.2% TS, mostly ash

Key Technical Factors

1. Limited long term trial data.
2. Abrasion could be a problem if not prefiltered.
3. 40µm prefiltration reduces viscosity and improves performance.
4. Centrifuge performance and residual free oil is important for cleaning.
5. Fish variety and storage times are important.

Key Commercial Factors

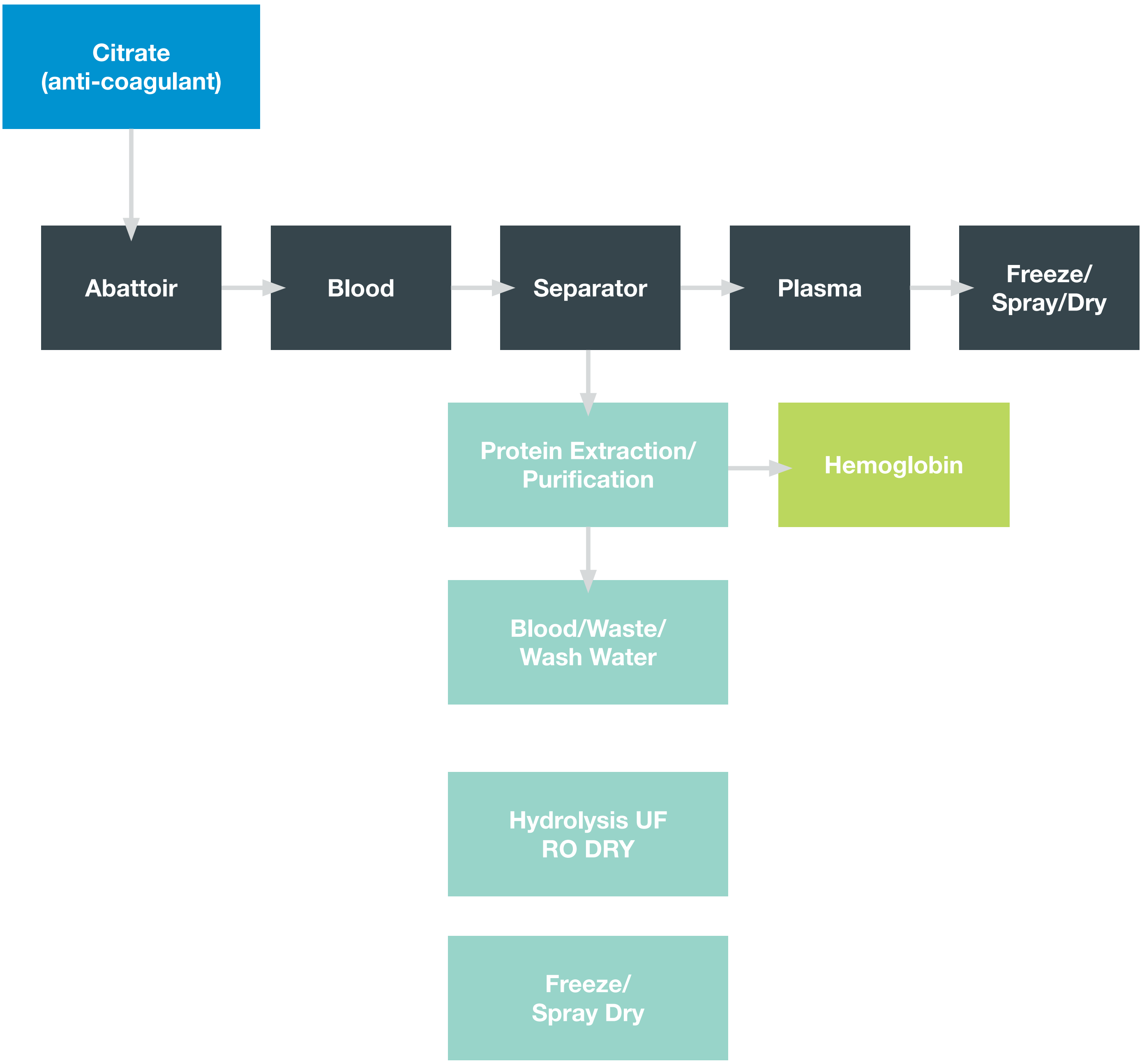
1. Seasonal 100 - 180 days per year.
2. 1- 2 effect evaporators USA, 3 effect Norway.
3. Achievable potential obviously lower. Waste heat evaporator + RO is cheaper to get to the minimum 30% TS necessary to add back to the meal. Suited to tubular design.
4. Alternative products tried, customers prefer PCI Membranes.

BLOOD WHOLE / PLASMA / WASTE

BLOOD WHOLE PLASMA/ WASTE PROCESSING

Through Reverse Osmosis

PROCESS DESCRIPTION



Liquor Characteristics

Blood 18 - 20% TS
Serum/Plasma - 9% TS (7% protein)
- VCF1 2 cP at 4°C, 4 cP at 25°C
- VCF3 80 cP at 4°C, 10 cP at 30°C

PCI Experience/Status

- On Site trials BRO/MSR - Y

Trial Location/Ref No.

- Diluted blood 15% TS - Freeze for pet food

Key Technical Factors

1. Heat Sensitive application.
2. Viscosity data important.
3. Limited experience.

Key Commercial Factors

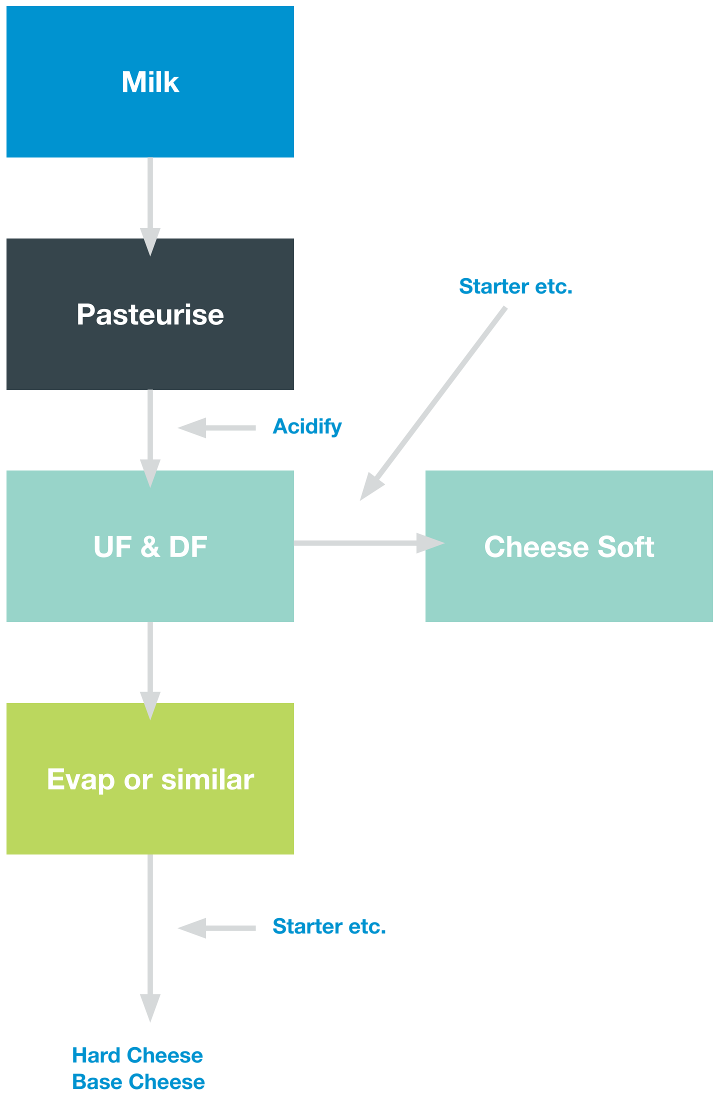
1. Incorporate within a larger process line.
2. Related applications.
   - Gluewater (A-L) or stickwater (Abcor NZ)
   - Hydrolysed pork entrails (Gamma, SEFC)

ULTRAFILTRATION FOR CHEESE

CHEESE PROCESSING

Through Ultrafiltration

PROCESS DESCRIPTION



Liquid Characteristics

- Whole or Skimmed Milk
- All cow breed dependant

PCI Experience/Status

- Lab. PCI BRO/BUF -N
- On Site trials BRO/MSR -Y
- Reference Plant -Y

Trial Location/Ref No.

- Ref Plant ROP 1011 and 1419

Budget Design Data	
Flux range	20 - 30 l/m^2/h
Max concentrations	5 to 7 times feed
Temperature	50 - 55°C
Pressure	10 bar max - approx 25% TS Skim - approx 40% TS Whole
Permeate Characteristics	Similar Whey UF permeate

Key Technical Factors

1. UF limited by viscosity.
2. Key process is downstream of UF - requires cheese process.
3. Soft cheese applications ES 625.

Key Commercial Factors

1. Market is dominated by Spiral membranes.

CLARIFICATION OF APPLE JUICE

CLARIFICATION OF APPLE JUICE

Through Ultrafiltration

PROCESS DESCRIPTION

Press Juice → Enzyme Depectinisation → UF Topped Batch → Product Storage or Concentration

Liquor Characteristics

CONCENTRATION	- 9 to 12° Brix	pH 2.5 to 4.0
PULP	- < 2%	

PCI Experience / Status

Several reference plants:

- Expanded global coverage with over 100 installations

Budget Design Data	
Temperature	50°C
Pressure	1.0 - 5.5 bar Inlet 5.5 bar Inlet pressure 1.0 bar outlet pressure
Permeate Clarify Required	< 1.0 NTU achievable with FP200

Design Data		
Suspended Solids	Design Flux	Design Max
Pressed Juice	120 l/m²/h	40%
Enzymatically Extracted	60 l/m²/h	20%

%Total Solids	Design Flux
15	110 l/m²/h
17	100 l/m²/h
24	100 l/m²/h

Aroma stripped juice has higher TS and fluxes.

Key Technical Factors

1. Complete depectinisation important to achieve design fluxes.
2. High yields required.
3. Topped batch operation with recycle around batch tank maximises flux.
4. Retention of haze-forming materials important.
5. Permeate clarity required < 1.0 NTU achievable with FP200.

Key Commercial Factors

1. PCI product fluxes higher then others in market area.
2. Traditional process involves enzymes fining agents and dead-end filtration.

BEER TANKS BOTTOMS

BEER RECOVERY

Through Ultrafiltration

PROCESS DESCRIPTION

1. Conditioning tanks, recovered beers, etc.
2. Fermentation tanks - contain yeast

Liquor Characteristics	
Colour	45° p real extract
Bitterness	28 EBU
Temperature	10 -12°C
Fermentation	20% v/v yeast

PCI Experience/Status

- On Site trials BRO/MSR -Y

Budget Design Data	
Flux range	10 - 20 l/m²/h ES625 20 - 40 l/m²/h FP100
Max concentration	Customer specific
Temperature	50 - 55°C
Pressure	0 - 5 bar
Permeate Characteristics	Maximum passage, colour, taste, bitterness and proteins

Key Technical Factors

1. Different processes/different beers/different requirement.
2. FP100/FP200 appears optimum - 'most open' but also consider LP 450 in LM 02
3. EACH application is unique.

Key Commercial Factors

1. Up to 10% of beer can be recovered or improved.
2. Centrifuges may be used for yeast.
3. RVF + carbon may be used. UF claimed to give better product.
4. Microfiltration might be a better process (0.25 LM 02 membrane).

EGG WHITE PROCESSING

EGG WHITE PROCESSING

Through Ultrafiltration

PROCESS DESCRIPTION

- Volume reduction before transportation and/or spray drying.
- May also be used to de-salt after lysozyme extraction (adding salt, precipitating and centrifuging).

Liquor Characteristics

• Egg White 12% TS (90% protein) (whole egg = 24%)	- 4 cP at 15°C ; (14 cP at 15°C/24% TS) - 5 cP at 50°C - 10 cP at 20°C

PCI Experience/Status		Trial Location/Ref No.
• On Site trials BRO	-Y	
• Reference Plant	-Y	• 2 off $10m^2$ systems

Budget Design Data	
Flux range	15 - 20 l/m²/h
Max concentration	2x VCF
Temperature	45 - 50°C
Pressure	2.6 - 8.8 bar Twin Entry
Permeate Characteristics	No protein loss

Key Technical Factors

1. Above data on Twin Entry ES 625.
2. Delta P is 6 bar at VCF1, 6.2 bar at VCF2.
3. Max temperature 50°C to avoid coagulation and pump damage.
4. Some unquantified differences in ultrafiltered product but used successfully in products.

Key Commercial Factors

1. UF removes glucose which causes browning without UF, fermentation glucose gluconic acid is used.

ANTIBIOTIC BROTH

ANTIBIOTIC BROTH
Through Ultrafiltration

Process Fluid General Description

Broths fall into two categories, whole broth and filtered broth.

Whole broth is a suspension of Mycelia, which may have been homogenised. The continuous phase contains the antibiotic, which is the desired product, as well as dissolved proteins and residual nutrients. The high level of suspended material imparts non-Newtonian rheological behaviour to these broths. In general, these broths are shear thinning.

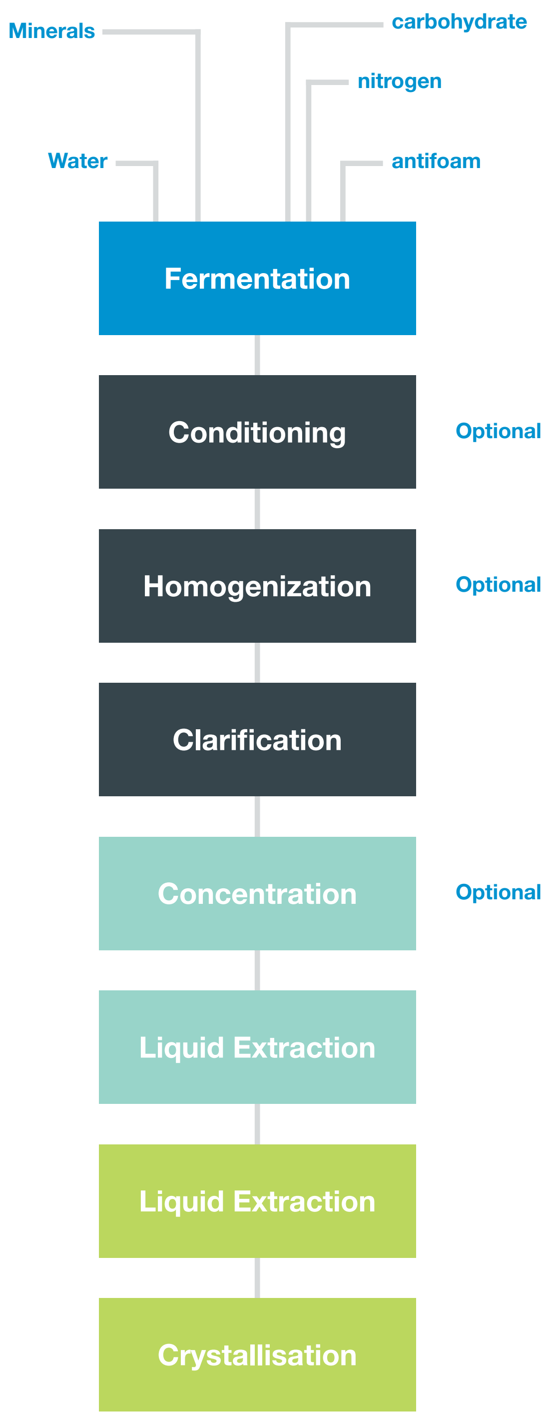
Filtered broths have much smaller amounts of suspended material than whole broths. Because of this, the rheology tends to be Newtonian until high concentration factors are achieved.

The properties of a broth will be affected by the type of antibiotic being produced and the recipe of the broth, or media. Broths also vary with natural, unquantifiable variations in the media, strain of mycelia or fermentation conditions. These can affect the performance of all downstream processing operations.

"We have one active site in Italy which is using PCI Membranes to process their broth"

Physical Proponents	Whole	Filtered
pH		
Suspended Solids	4% - 8% wt/wt	0.5% wt/wt
Total Solids	8% - 16% wt/wt	
Rhelogy	μa = 30-70 mP a.s $^{-1}$	
Mol. Weight	334	
Pk	2.5 - 3.1	

PROCESS DESCRIPTION



Fermentation

This is usually carried out in batch stirred tank fermenters. Batch volumes can be up to 180m³ and batch times are normally around 5 to 6 days for Peniclin. At the end of the fermentation it is normal to cool the broth to prevent the antibiotic from degrading.

The media used for fermentations can be either “defined media”, or, “undefined media.” In defined media the ingredients are all relatively pure, eg. glucose, so the components are fully known. This type of media is ‘not’ common for bulk antibiotics. Undefined media uses less pure materials such as molasses for carbohydrate and blood as a nitrogen source.

The mycelia require carbohydrate, nitrogen, trace minerals and a suitable pH for growth. In addition, antifoam is commonly used.

Conditioning

This step is optional and does not apply to all broths. It involves conditioning the broth to make clarification easier. There are four principal options:

1) AGING - In some broths the mycelia will flocculate naturally when the fermentation stops.

2) HEAT TREATMENT - To induce flocculation.

3) pH ADJUSTMENT - To induce flocculation.

4) ADDITION - Flocculents.

If the antibiotic is intracellular, this step is necessary to release the antibiotic from the cells. The process may be carried out using a homogeniser, or by ball mill. The operation is often referred to as cell disruption.

Homogenisation

If the antibiotic is extracellular, this step is optional. However, it does reduce the viscosity of the broth, which may aid processes further downstream.

Clarification

The traditional techniques are filtration using rotary vacuum filter (RVF) and centrifugation. Ultrafiltration can replace both, ot it can be used in conjunction with either.

Concentration

In some processes, the clarified broth is concentrated before further processing. Evaporators or RO may be used.

Extraction

This is usually done by liquid/liquid extraction. The antibiotic is extracted from the aqueous phase into an organic phase. It may then be transferred back to an aqueous phase prior to crystallisation.

The extraction stage is hindered by the presence of proteins in the clarified broth and surfactants are added to improve the extraction.

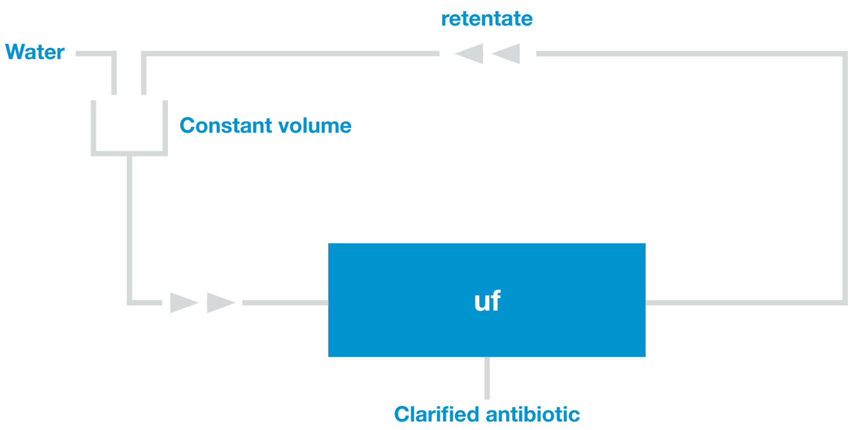
Crystallisation

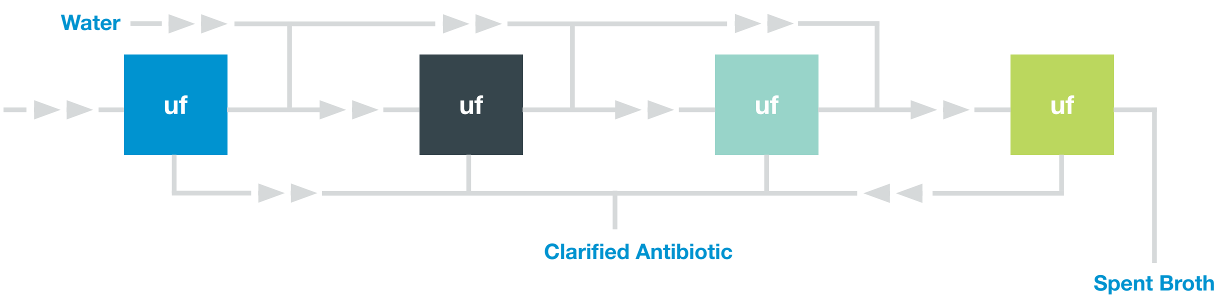
Here the crude antibiotic is crystallised out. In some cases this involves further washing and purification. The crude antibiotic is then either used as a feed stock for the manufacture of “synthetic” antibiotics, or it is formulated into commercial drugs.

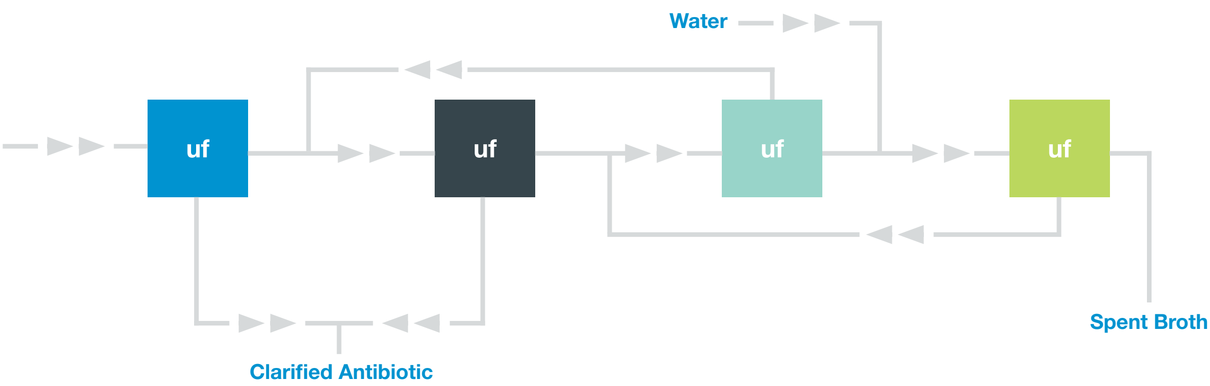
Ultrafiltration

Whole Broth

Due to the high viscosity of the broth the maximum concentration factor achievable is very low, ranging from 1 to 3. Therefore, in order to attain yields of >95% diafiltration must be employed. There are 3 basic ways of doing this:







Note:

In the continuous plants the first stage carries out a concentration of the broth. This concentration is maintained throughout the rest of the plant. The advantage of concentrating the broth is that it reduces the diafiltration requirement and gives higher concentration of antibiotic in the bulk permeate, which is a clear advantage to further downstream processes. The membranes used in this stage are the same as those used in the rest of the plant.

Filtered Broth

Filtered broth can be concentrated to volumetric concentration factors (VCF) of up to 50 times. This obviously reduces the need for diafiltration, thus a normal plant would either be batch, or co-current diafiltration.

Comparison of Plant Options

	Batch	Co-Current	Counter Current
Residence time	High	Low / Medium	Low / Medium
Operation	Easy	Medium	Difficult
Automation	Easy	Medium	Complex
Control	Easy	Medium	Complex
Water Usage	Low	High	Medium / Low

Process Design

	Flux	Solute Passage
Penicillin G	20 - 30 l/m^2/h	100%
Cephalasporin C	12 - 40 l/m^2/h	No Data
Clavulanic Acid	25 - 30 l/m^2/h	No Data
Penicillin V	100 - 160 l/m^2/h	100%
Protein	-	0-10%

Due to the high yield requirements, even a small retention of the antibiotic can have a major impact on the plant size and diafiltration requirement.

Note:

Flux is a function of concentration factor. However, the variation from batch to batch of broth makes it impossible to quote a general equation. It is normal to design on an average flux determined during trials.

The above fluxes represent the results of different trials conducted at different sites at different times. Therefore, they are not necessarily the maximum fluxes achievable with current membranes. See membrane types below.

Pressure

8 - 12 bar module inlet, 2 bar module outlet
Delta P = f (broth, vcf)

Temperature

10 - 25°C

This depends on the customer and the residence time in the plant. At higher temperatures the antibiotic tends to degrade due to the action of enzymes

pH

No adjustment is required

Cross Flow

Nominal ~ 4 m/sec. (=30 L/min)
Range ~ 2.6 - 4 m/sec. (=20 - 30 L/min)

There is no contradictory evidence as to whether or not flux is a function of cross flow velocity. Previous quotes have been based on 4 m/sec. but there is potential to optimise the velocity. It should be noted that, due to the non-newtonian rheological behaviour of whole broth, reducing cross flow velocity may not always reduce the pressure drop.

Cleaning

This cleaning procedure has proved successful for PU 120 in trials lasting more than one year. See membrane life below.

Membrane Life

6 months to 1 year.

This is based on extensive trials on 100 sets of PU120 membranes, cleaned once per day. After 6 months, the passage of proteins starts to increase.

Application Status - Penicillin G

Large scale trials have been carried out using PU120 membranes. Batch trials, principally on filtered broth, using >100m^2 membrane area and counter current diafiltration on a three stage plant of 26m^2 have been conducted at two different sites.

Trials Required

Due to the nature of the industry and the variability of broths, trials will be required before firm quotes can be given, providing no difficulties are encountered in cleaning. The trials need to be extensive.

INTRODUCTION TO ULTRAFILTRATION

Ultrafiltration (UF) is a variety of membrane filtration in which hydrostatic pressure forces a liquid against a semi permeable membrane. Suspended solids and solutes of high molecular weight are retained, while water and low molecular weight solutes pass through the membrane.

Ultrafiltration systems eliminate the need for clarifiers and multimedia filters for waste streams to meet critical discharge criteria or to be further processed by wastewater recovery systems for water recovery. Efficient Ultrafiltration systems utilise membranes which can be submerged, back-flushable, air scoured, spiral wound UF/MF membrane that offers superior performance for the clarification of wastewater and process water. The products and applications detailed in the following section, all utilise our membrane technology in the Ultrafiltration process.

TWIN ENTRY FLOW
Configuration

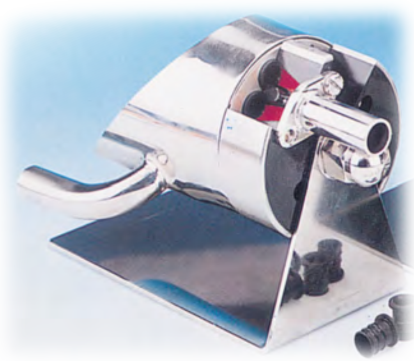
Each Ultrafiltration module comprises 18 perforated stainless steel tubes in the form of a shell and tube, each tube is fitted with a membrane element. Flow of the process fluid through each of the tubes is effected by specially designed end caps providing 2 parallel channels, each of 9 tubes in series. This allows viscous materials to be processed and high cross flow velocities to be used with acceptable pressure drop.

For non-viscous materials with operation at high pressure (RO conditions) an alternative end cap arrangement is available which results in lower energy consumption.

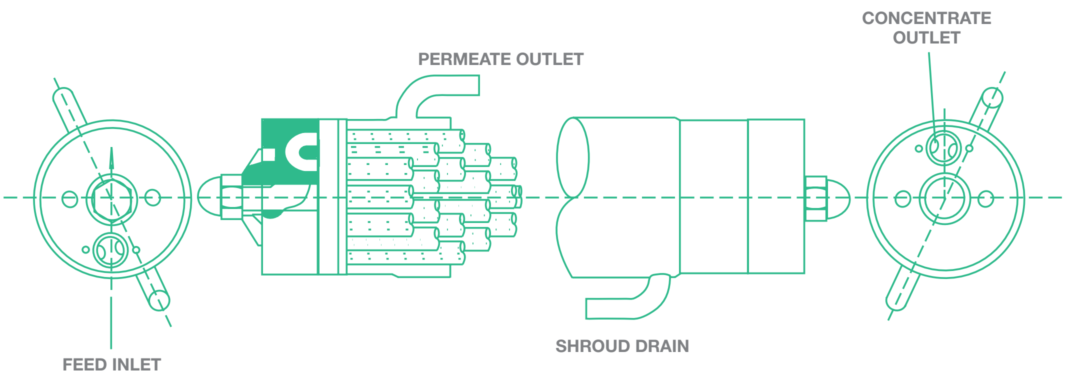
The open channel, highly turbulent flow design allows a wide variety of process liquors to be concentrated, with minimal pretreatment. High levels of suspended materials can be tolerated. The design is free of dead spaces, which reduces the fouling potential of the membranes while ensuring maximum effectiveness of cleaning.

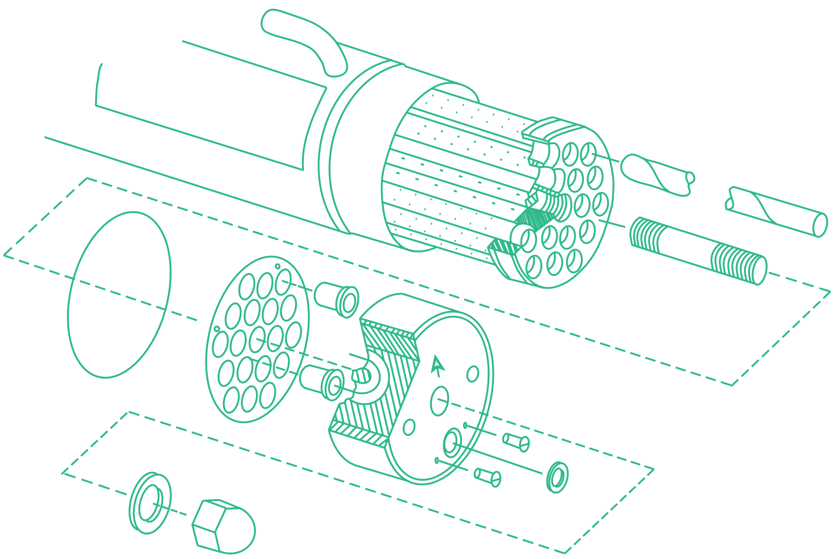
Twin Entry Flow Arrangement

An end cap type known as twin or double entry that provides two flow paths, of nine tubes in series. This allows viscous materials to be processed and higher cross flow velocities to be used, minimising the overall pressure drop.



B1 UF Module Assembly





Module Length (m)	Membrane Area (m^2)	Weight Empty (kg)	Hold-up Volume Tube-side ()	Hold-up Volume Shroud-side (L)	Membrane Tube ID. (mm)
2.44	1.75	24.7	5.6	13.3	12.7
3.66	2.63	34.5	8.4	20.0	12.7

Connections	
Permeate/Drain	0.75 inch OD for flexible hose
Feed/Concentrate	0.75 inch OD oval flange

Tube-Side Mechanical Operating Limits	
Operating Pressure	Up to 16 bar max
Pressure Drop	10 bar max
Operating Temperature	Up to 80°C
Shroud Material	AISI 316 Stainless Steel
Membrane Type	A range of MF & UF Membranes

PARALLEL FLOW
Configuration

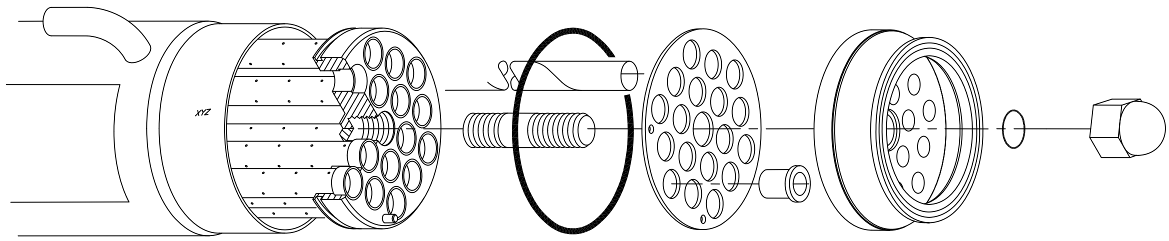
Each module comprises 18 perforated stainless steel tubes in the form of a shell and tube, each tube is fitted with a membrane element. Flow of the process fluid through each of the tubes is effected by specially designed end cap providing 18 parallel channels.

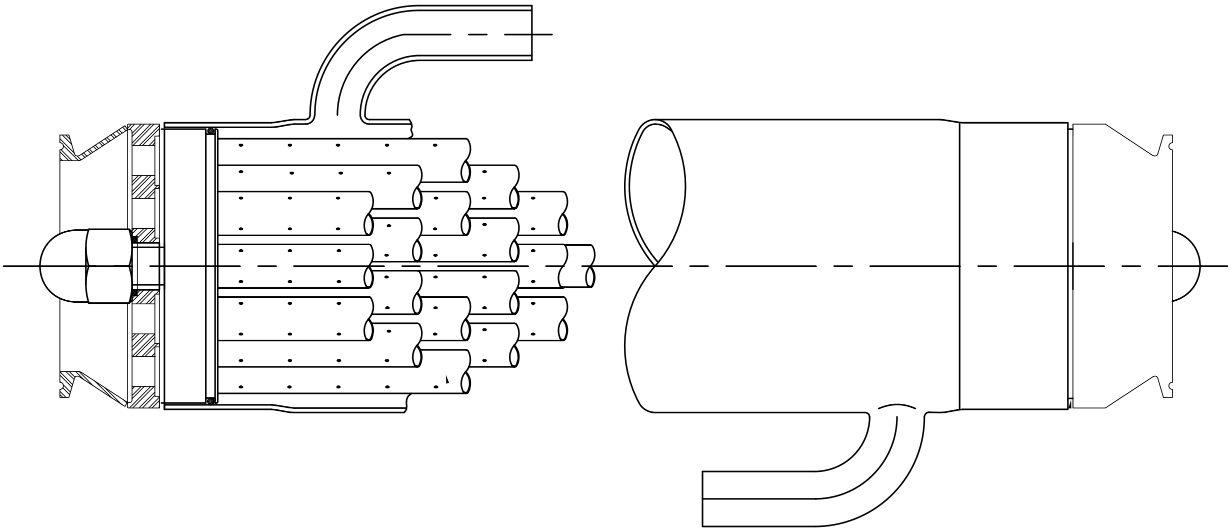
This allows viscous materials to be processed and high cross flow velocities to be used with acceptable pressure drop. For less viscous materials an alternative end cap arrangements are available which results in lower energy consumption.

The open channel, highly turbulent flow design allows a wide variety of process liquors to be concentrated, with minimal pretreatment. High levels of suspended materials can be tolerated. The design is free of dead spaces, which reduces the fouling potential of the membranes while ensuring maximum effectiveness of cleaning.

Parallel Flow Arrangement
This end-cap allows all 18 tubes to operate in parallel permitting the highest crossflow velocities to be used with acceptable pressure drop.

B1 Parallel Flow module

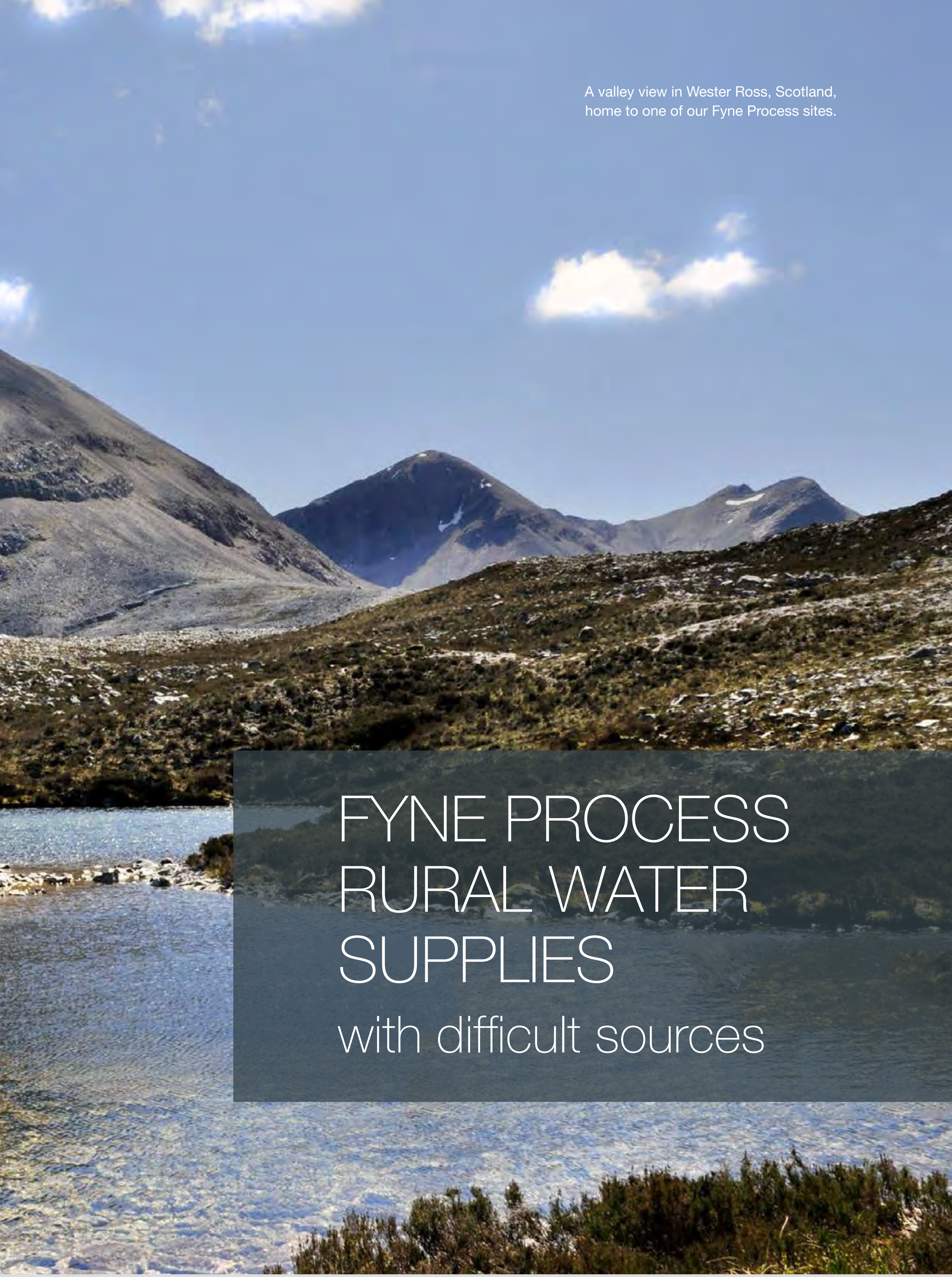




Module Length (m)	Membrane Area (m^2)	Weight Empty (kg)	Hold-up Volume Tube-side (L)	Hold-up Volume Shroud-side (L)	Membrane Tube ID. (mm)
2.44	1.75	24.2	6.4	13.3	12.7
3.66	2.63	33.8	9.2	20.0	12.7

Connections	
Permeate	0.75 inch OD for flexible hose
Feed	For 2½” Tri-Clamp

Tube-Side Mechanical Operating Limits	
Operating Pressure	Up to 16 bar max
Pressure Drop	10 bar max
Operating Temperature	Up to 80°C
Shroud Material	AISI 316 Stainless Steel
Membrane Type	A range of MF & UF Membranes



A valley view in Wester Ross, Scotland, home to one of our Fyne Process sites.

FYNE PROCESS RURAL WATER SUPPLIES

with difficult sources

THE FYNE PROCESS™

UF & NF Municipal Water Processing

The Fyne Process is a simple, single stage process that employs advanced membrane filtration technology, together with screening, post conditioning and disinfection, to treat poor quality, variable water sources for municipal drinking water supply in rural small communities of up to 6,000 people.

It has been proven to provide the least expensive operating costs for small to medium sized systems, with installed plants having capacities ranging from 3m^3/day to 1500m^3/day. The Fyne Process is particularly suited to water sources containing carbonaceous organic colour and pathogens such as Cryptosporidium.

Applications

The Fyne Process provides a filtration barrier to the following contaminants (amongst others):

- Organic carbon - the principal pre-cursor of disinfection by-products (e.g. carcinogenic THMs)
- Pathogens - including bacteria, protozoan cysts (e.g. Cryptosporidium) and viruses
- Metals - including iron, aluminium and manganese
- Turbidity - Suspended Solids and algae.

Fyne Process does not require the use of potentially expensive coagulants

The Fyne process does not require coagulants as the membranes operate at a molecular level. Consequently, the process does not generate sludge and maintains a high quality of treated water in spite of both sudden and substantial changes in raw water quality.

Conventional treatment processes often remove fine contamination (such as colour and pathogens) using chemical coagulants, which have various drawbacks, including:

- Delayed response to changes in raw water quality, causing process performance failure.
- Health and safety concerns for operational staff and the environment
- Transportation issues and specialist on-site handling and storage requirements
- Production of chemical bearing sludge, requiring costly removal re-processing and disposal.

Fyne Process typically has a £200/yr chemical cost, compared to more than £38,000/yr for conventional coagulation chemistry'

When compared to the conventional coagulation chemical process the Fyne Process offers substantial savings to chemical costs, substantial saving in operator attendance, savings in waste disposal costs. Less equipment is required and maintenance costs are reduced with this process. Manpower & maintenance requirements are a significant part of the conventional process operational cost.

Over 70 worldwide installed plants with capacities ranging from 3m^3/day to 1500m^3/day

Since its development in 1992, more than 80 Fyne Process plants have been installed across the world, principally in Scotland, Canada and the USA. The process has been verified and approved by the following: US Environmental Protection Agency's "Environmental Technology Verification" program, UK's Drinking Water Inspectorate and the Scottish Executive. The proven performance of the Fyne Process over extended time periods has resulted in being specified as a preferred treatment solution, thus giving PCI Membranes confidence in offering robust performance guarantees.

Fyne Process and Package Membrane Plants (PMP's) are well-suited for water systems of small and medium sized rural communities.

Package Membrane Plants

PCI Membranes innovatively introduced Package Membrane Plants (PMPs) for the Fyne Process, offering the following features:

- Reduced costs and delivery times.
- Performance testing prior to shipping - minimising on-site commissioning.
- Application of single phase electrical supplies as power sources for smaller sites - easing installation in remote locations.
- Minimal footprint (see below images).

As the PMPs are supplied as complete treatment processes incorporating all the necessary peripheral items, they simply require positioning within a building and connection to services before final performance validation. Full instrumentation can be incorporated to enable unattended monitoring and limited site attendance. Custom engineered plants are offered for larger capacities and/or specific customer requirements.

Drimin PMP 24 m^3/day output

Achnasheen PMP 50m^3/day output

PMP's are easily placed on site with a small footprint.

Strontian PMP (Interior) 420m³/day output

Strontian PMP (Exterior) 420m³/day output

Membrane Filtration Technology

PCI's C10 Series module and its 12.7mm diameter tubular membranes - against Spirals (0.8mm) or hollow fibre (1.2mm) - are used in the Fyne Process due to its ability to handle suspended solids without blocking. The tubular membranes retain contaminants on the raw water side and allow potable water to permeate through the membrane.

The deposition of impurities upon the membrane's surface is minimised by maintaining a high crossflow velocity using a partial re-cycle flow, thereby sustaining high filtration efficiencies. As the process waste stream is simply concentrated raw water, there are no environmental concerns to prevent the return of the concentrated waste stream to the local water course.

Membrane Filtration Technology

The membranes are routinely cleaned using a mechanical pigging technique employing natural foam rubber balls (see image right). The foam ball cleaning of a membrane was developed by PCI as a way to simplify the cleaning process as well as helping reduce overhead costs.

The mechanical pigging technique can be automated, thereby reducing operators attendance and costs as well as minimising chemical consumption and waste disposal. This innovative technique affords lower chemical costs per year.

After a predetermined operational time the plant's flow direction is automatically reversed, passing the balls along the length of the membrane tubes and scouring the accumulated deposits from the membrane surface. The removed deposits are discharged via the waste stream to the local water course.

This unique feature makes the Fyne Process more environmentally sensitive than all conventional treatment alternatives. Although a number of disposal options are available to the Water Authority, waste disposal issues are site specific and require consent from the appropriate environmental authority. As the process waste stream is simply concentrated raw water, there are no environmental concerns to prevent the return of the concentrated waste stream back to the local water course.

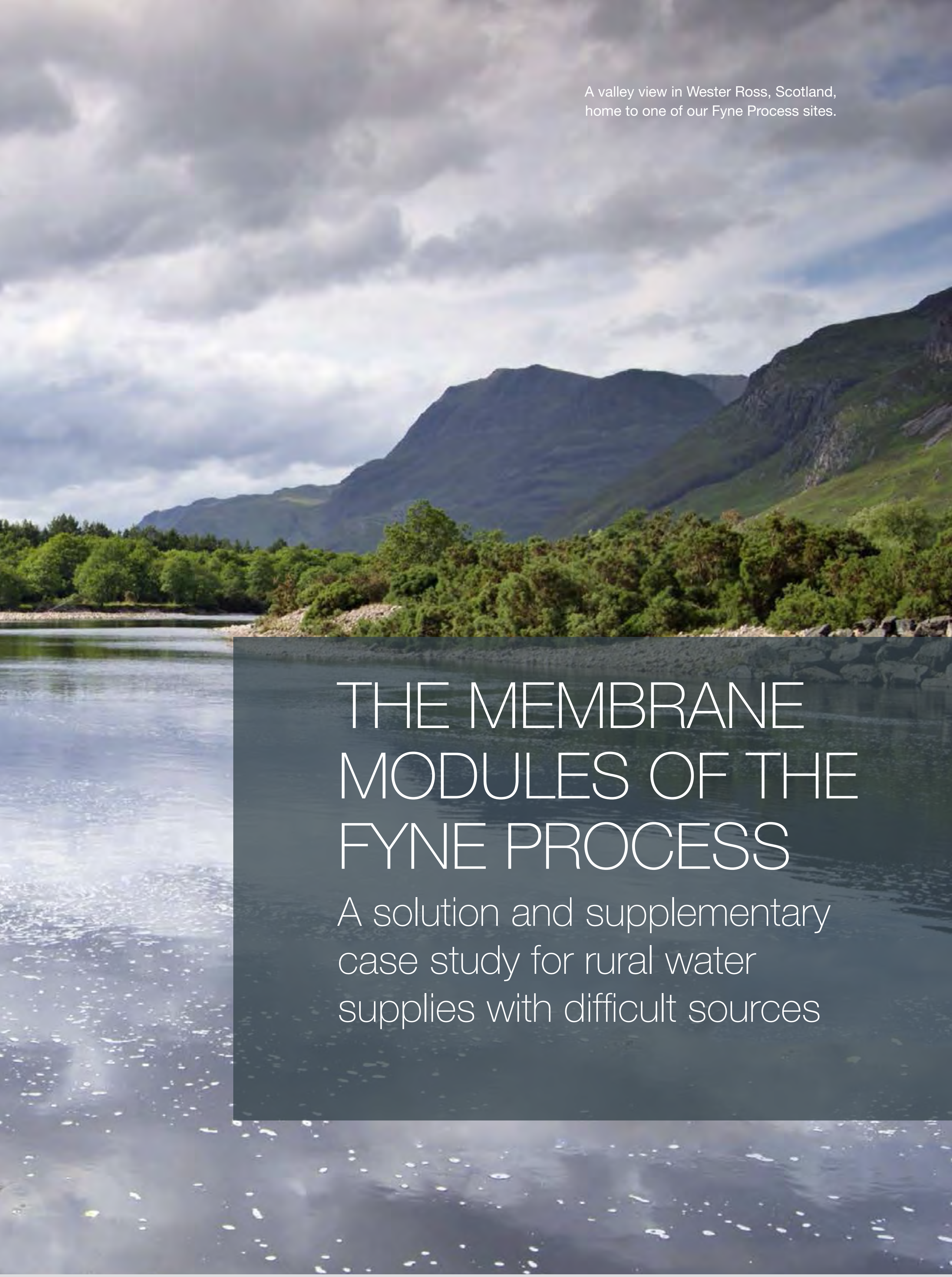
Membrane cleaning can be done mechanically with the use of foam balls and chemically using established clean-in-place techniques at extended frequencies, typically 4 times a year.

The membrane treatment plants provide a robust and reliable treatment process for use in remote locations, which require little-to-no operator input. Operator input is required to monitor the plant, recharge chemicals, take regular samples and on occasion chemically clean the membranes.

The biggest difference for the operator is the number of required facility visits, (see table below). The savings to be gained is greater for the most remote sites, where operators spend significant amounts of time travelling between treatment works. An additional benefit, is that overhead costs are lowered with the number of water quality failures being reduced, allowing staff to go about their normal duties.

PCI have also extended our membrane life guarantees from the 1 year period offered on the early plants to 3-5 years offered on the more recent plants, reducing the overall membrane plant OPEX. Experiences in the West of Scotland show that some membrane plants have benefited from significantly longer membrane life than the increased guaranteed life of 3-5 years, which will further reduce operating costs.

Treatment Works	Treatment Process	Operator Duties	Average Hours Per Day
Ardrishaig	Dissolved air flotation and two-stage filtration. Sludge thickener & plate press	Water quality checks	1.0
		Floc test	0.5
		Chemical batching	1.0
		Sludge plant	0.5
		Instrument calibration	0.5
		Housekeeping	0.5
		Total	4.0
Tighnabruaich	Pressure sedimentation and two stage filtration (now a tubular membrane plant)	Water quality checks	1.0
		Floc test	0.5
		Chemical batching	1.0
		Filter backwash	2.5
		Instrument calibration	0.25
		Housekeeping	0.25
		Total	5.5
Bunessan	Spiral Membrane plant	Chemical batching & clean	1.0
		Housekeeping	0.05
		Total	1.05



A valley view in Wester Ross, Scotland, home to one of our Fyne Process sites.

THE MEMBRANE MODULES OF THE FYNE PROCESS

A solution and supplementary case study for rural water supplies with difficult sources

C10 SERIES

The C10 module offers the user an economical tubular module which can be fitted with a wide range of proven nanofiltration and ultrafiltration membranes.

The module has been developed to improve the competitiveness of tubular membrane plants, especially at larger capacities. It can be operated up to 12 bar at 20°C.

Dimensions			
Length (m)	3.66	1.83	0.92
Membrane Area (m^2)	10.5	5.2	2.6

Additional Details	
Operating Pressure	Up to 12 bar max
Operating Temperature	Up to 30°C
Shroud Material	ABS
Membrane Type	A range of UF and NF membranes
pH Range	Membrane specific

Simple Manifold Connections
Easy plant maintenance, reduced remembraning time

ABS Construction
Lightweight, robust

Modular Design
Quick and easy plant construction

Tubular Module
Minimal prefiltration required

C10 Series Tubular Membrane Module

ACHNASHEEN WATER TREATMENT WORKS

Fyne Process Case Study Using C10 Series Tubular Membrane

Case Study: Achnasheen Wester Ross, Scotland

Introduction

Achnasheen is a village community of 120 people in Wester Ross, 40 miles North of Inverness in the Highlands of Scotland. Water from the Achnasheen burn has traditionally been filtered and chlorinated before being supplied to the village. The existing treatment process has consistently failed to meet Scottish Water's drinking water quality standards due to high colour passage, with the subsequent chlorination causing carcinogenic disinfection by-products to be generated in the form of Trihalomethanes.

Challenge

As with many Highland burn sources, the raw water at Achnasheen is both variable in quality and quantity, leading to peaks of colour and turbidity, particularly when the burn is in spate. Being an elevated site, cold temperatures and snow melt were design considerations, with water temperatures of less than 1°C being common in winter months. An overview of the raw water quality and treatment required is tabulated on the right. Scottish Water's product water specification also included a requirement to remove micro organisms to safeguard against pathogens.

Parameter	Units	Raw Water	Product Water
Colour	°Hazen	156	5
Turbidity	FTU	3	0.4
pH		5.5-8.0	8.0-9.5
Aluminum	µg/l	168	50
Iron	µg/l	1030	50
Manganese	µg/l	164	20
TOC	µg/l	11	2

Design

PCI Membranes broke new ground at Achnasheen in January 2004, with the installation of the first ever Fyne Package Membrane Plant (PMP). Developed to minimise cost and program duration, the PMP was constructed in a transportable building at PCI's production facility, where it was commissioned prior to shipment.

Raw water is conveyed 500m from the burn source to the PMP by gravity, with surge protection incorporated to protect against plant damage. At the core of the process are seven 3.6m long C10 tubular membranes each of which contains 72 membranes. Each module has a membrane surface area of $10.5m^2$, giving an overall plant membrane area of $73.5m^2$. The plant originally was designed to operate at a nominal flux rate of 24 $l/m^2/h$ at 10°C and a recovery rate of 85%. In 2005, Scottish Water contracted PCI to extend the plant to 50 m^3/day to keep pace with the increased local need.

REFERENCE

HEAT EXCHANGER PROGRAMME

HEAT EXCHANGER

Heat Removal and Calculations

Introduction

The B1 heat exchanger module is designed to remove input heat from pumps, valves and general head loss that generates heat in a process system. The heat exchangers are not designed to act as a means of increasing or decreasing process fluid temperature. A separate heat exchanger should be used if this is required.

B1 heat exchanger modules are designed to replicate head loss of a B1 module so as not to cause a pressure imbalance in the membrane stack.

Heat Removal Guide

The following equations and graphs will allow the number of B1 heat exchangers to be estimated.

If more specific calculations are required, please use first principles, consider the B1 module is made from 316 Stainless Steel and the material thickness is 1.6mm when calculating the heat transfer coefficient.

To calculate the temperature rise in a continuous plant, the following equation in **bold** can be used based on either the absorbed or installed power. Using the installed power allows for a greater safety factor otherwise a safety factor must be considered.

Temperature Rise

$W = m \times Cp \times \Delta T$ (kW)

which rearranged gives: $\Delta T = W/m \times Cp$ (°C)

where:
- W = work done (heat put in) by pumps in kW.
- m = fluid mass flow rate in kg/s.
- Cp = fluid specific heat in KJ/kg/°C.
- ΔT = temperature rise in °C.

For water like products
- Cp = 4.2 (kJ/kg/°C)
- m = Q x 1000/ 3600 kg/s.
- Q = fluid flowrate in m3/hr.

giving: $\Delta T = (W \times 3600)/(Q \times 1000 \times 4.2)$

$= 0.86 \times W/Q$ (°C)

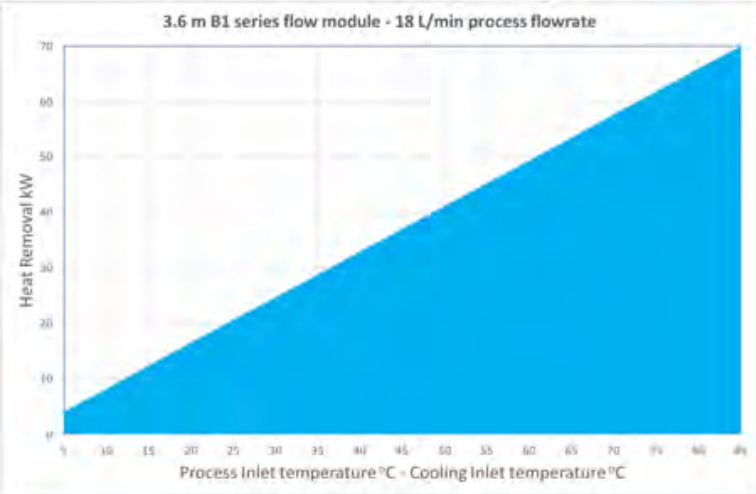
For a batch plant we must assume all the input heat must be removed to avoid a temperature increase over time. The 3.66m long B1 heat exchanger is designed to operate with an inlet cooling water flow of 25 l/min fitted with ¾" off-takes to reduce head loss and avoid back pressure which should be no greater than 2 bar max.

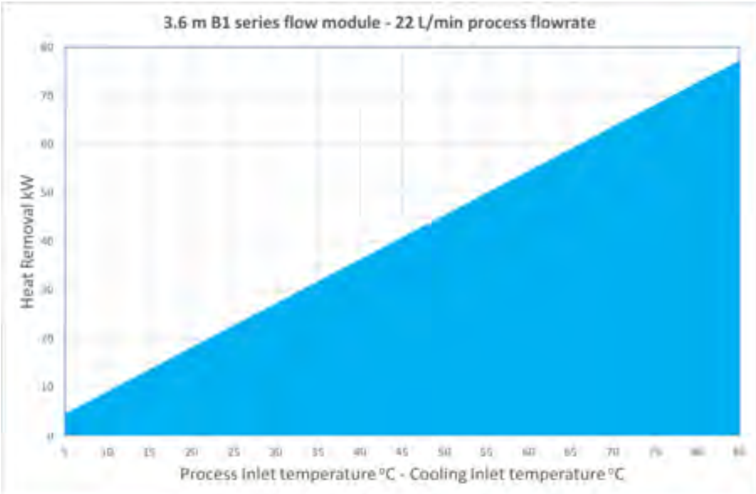
Heat Removal Charts

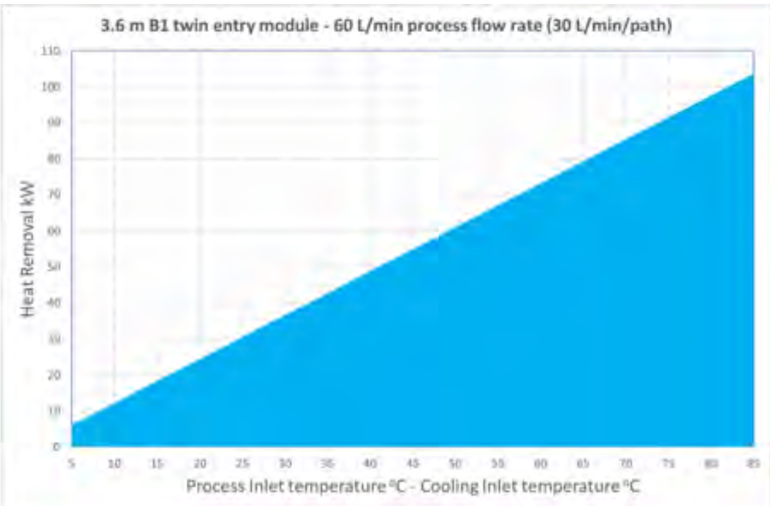
Using the following graphs, you can estimate the heat removed (Power in kW) by each B1 heat exchanger. In all cases the safe working area for the heat exchanger is represented by the shaded portion of the graph.

Remember when using B1 modules in series (2 or 3 depending on the design) the same number of heat exchangers must also be used to replicate the process head loss.

Where multiple stages are used in a design, each pump (Feed and Recycle Pumps) should be calculated and considered when selecting the number of B1 heat exchanger modules required.

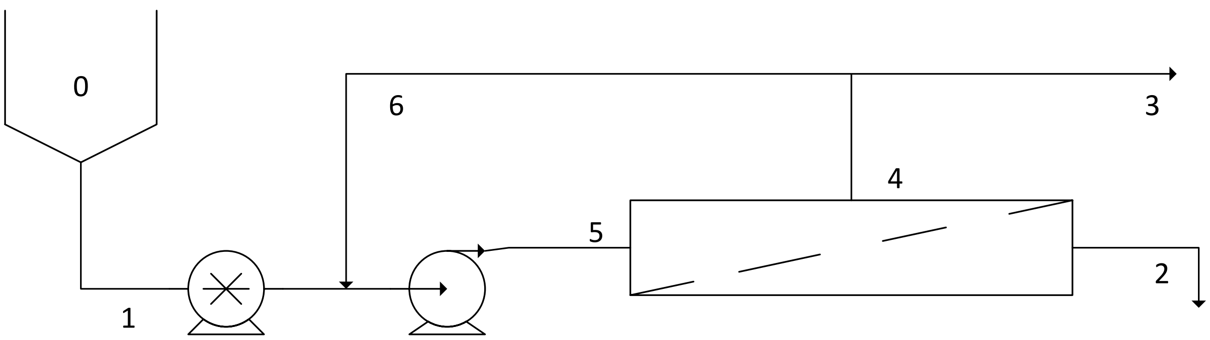






General Calculations

Flow	= Volume/Time	(l/h)
Feed Flow (1)	= Permeate Flow + Reject Flow	(m^3/h)
Permeate Flow (2)	= Membrane Area x Membrane Flux	(m^3/h)
Reject Flow (3)	= Feed Flow – Permeate Flow	(m^3/h)
Concentration Flow (4)	= Feed Flow – Permeate Flow	(l/h)
Module Inlet Flow (5)	= Application and Module End Cap Specific	(l/min)
Recycle Flow (6)	= (No. of module flow paths x Module Inlet Flow) – Feed Flow	(m^3/h)
Membrane Flux	= Permeate Flow/Membrane Area	(l/m^2/h)
Permeability	= Membrane Flux/Pressure	(l/m^2/h/bar)
Percentage Solute Passage	= (Permeate Quality/Feed Quality) x 100	(%)
Percentage Solute Rejection	= $\frac{\text{(Feed Quality – Permeate Quality)}}{\text{Feed Quality}}$ x 100	(%)
Recovery	= Permeate Flow/Feed Flow	(%)
Volume Concentration Factor	= Initial Volume/Final Volume	(VCF) – Batch
Volume Concentration Factor	= Feed Flow/Reject Flow	(VCF) – Once Through



Once through system design with feed and recycle pump.
In a batch concentrate system design the reject flow (3) returns to the tank (0).

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