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Membrane Technologies for Water Treatment

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Outline

- Some History
  - Early development
  - Tubular membranes
- Classifications
  - Microfiltration
  - Ultrafiltration
  - Nanofiltration
  - Reverse Osmosis
- Configurations
  - Tubular
  - Spiral wound
  - Hollow fine fiber
- Test Configurations
- Lake Arrowhead Demonstration Project
- Applications

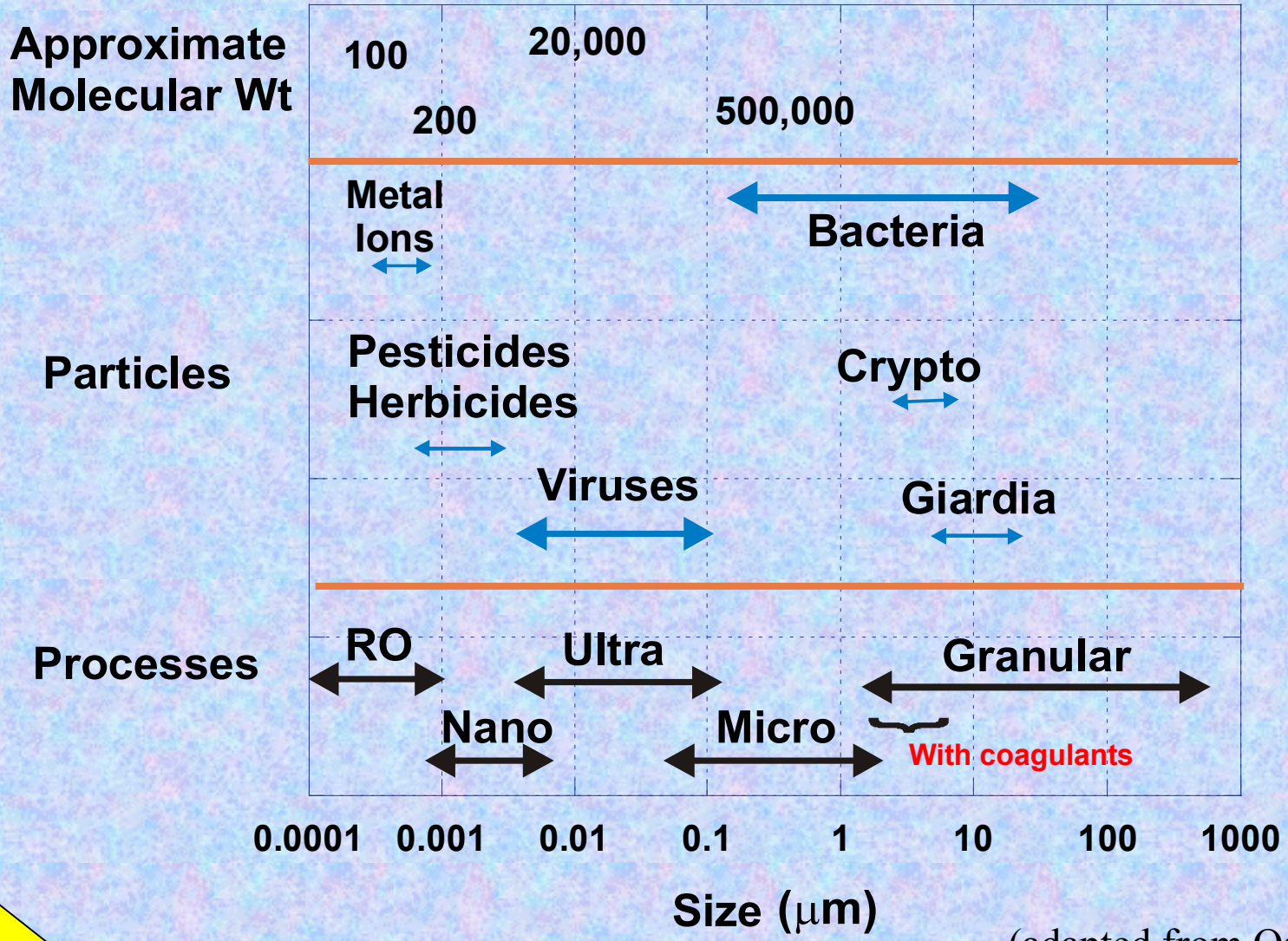
Original Invention

- Loeb-Sourirajan invented the Cellulose-Acetate membrane at UCLA in early 1960's. With UCLA they had the original patent, but it was never licensed due to its poor writing
- Originally used in a plate and frame apparatus
- Discovered accidentally that it was asymmetric
  - One-half of the time, their experiments worked, one-half of the time they failed
  - Only after analysis did they learn to orient the membrane correctly
- Later produced a tubular membrane that was commercially viable, and used in some small production facilities and several pilot plants

Classifications

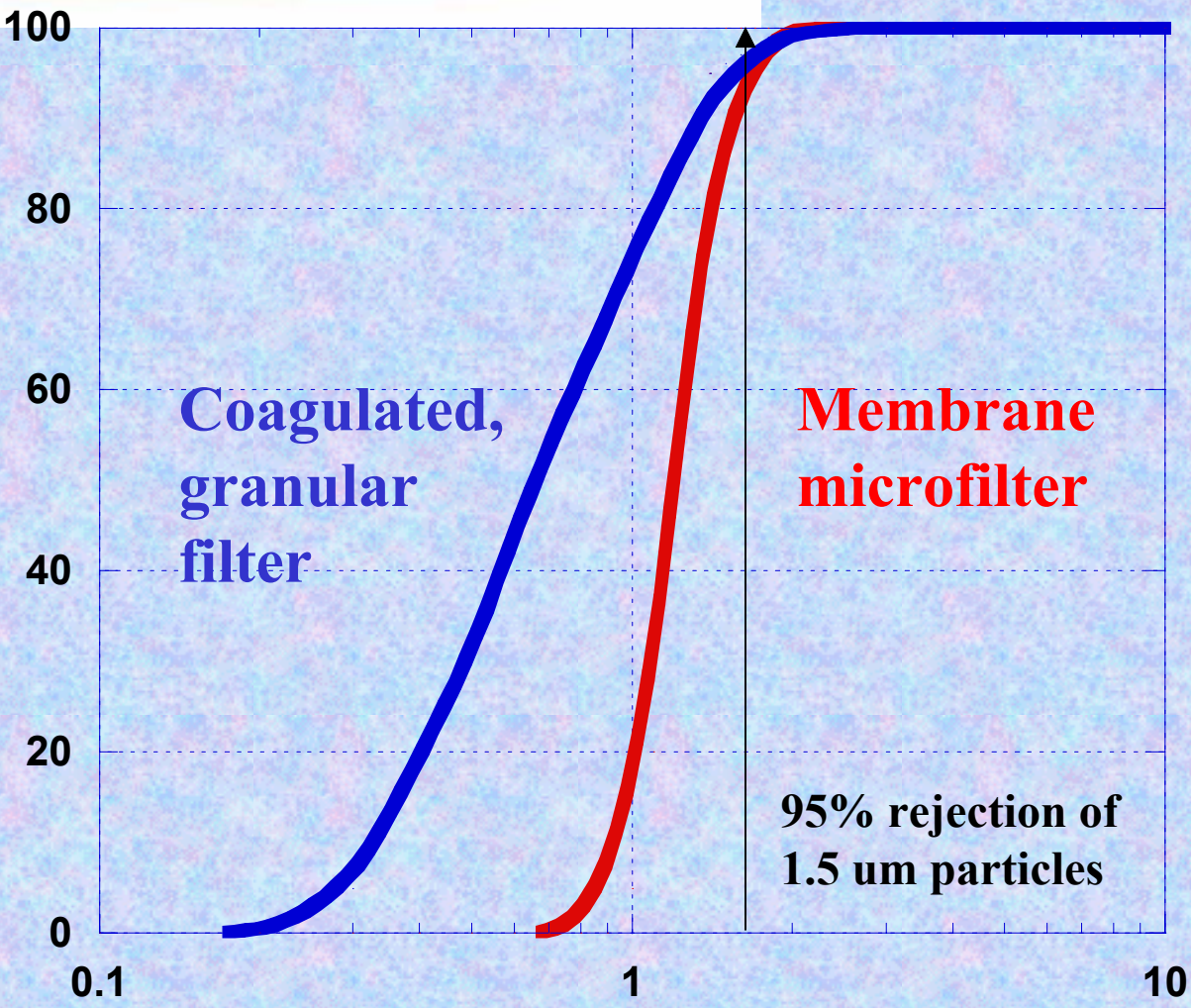
- **Microfiltration – cutoff 0.15 to 50 μm, ~ 200 kPa operation**
- **Ultrafiltration – 0.003 to 0.2 μm, > 3000 mw ~ 700 kPa**
- **Nanofiltration – 0.001 to 0.003 μm, 200–10,000 MW, ~ 700 kPa**
- **Reverse osmosis – 0.0005 μm, < 200 MW, ~3000 kPa for reclamation, ~ 10,000 kPa for seawater**

Particles and Processes



(adapted from Osmonics)

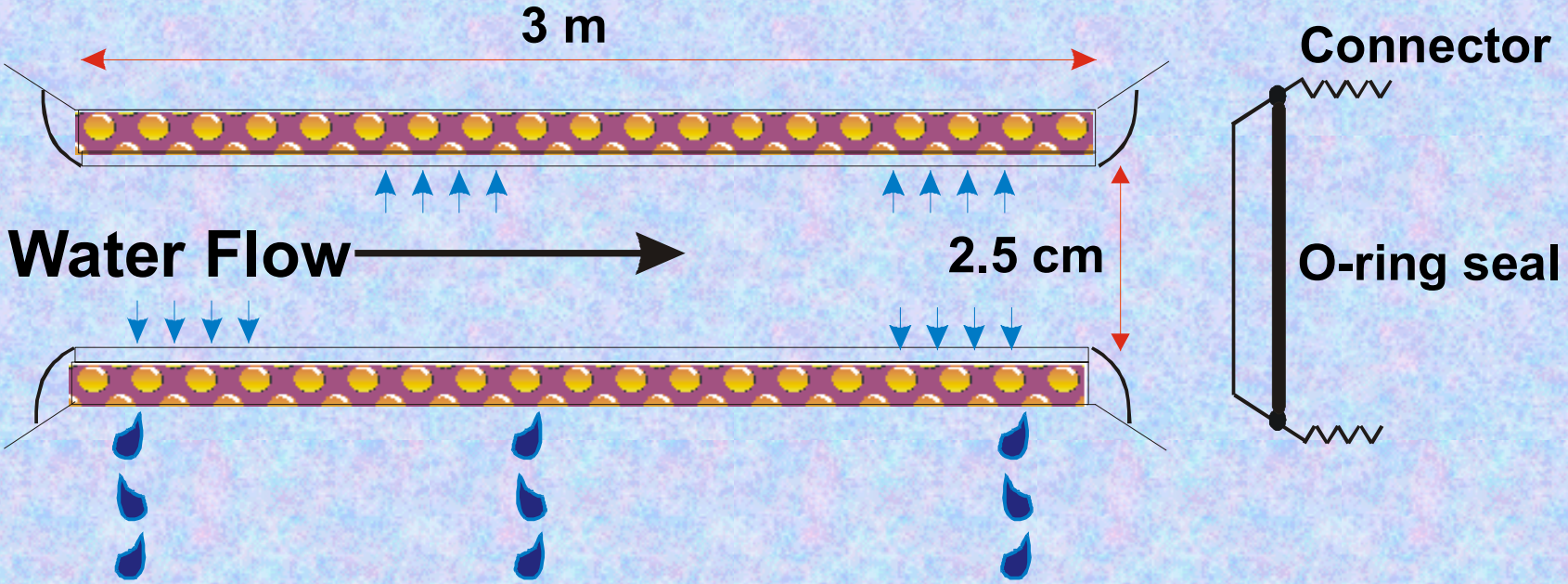
Sharper Cutoff Allows More Control



Tubular Membranes

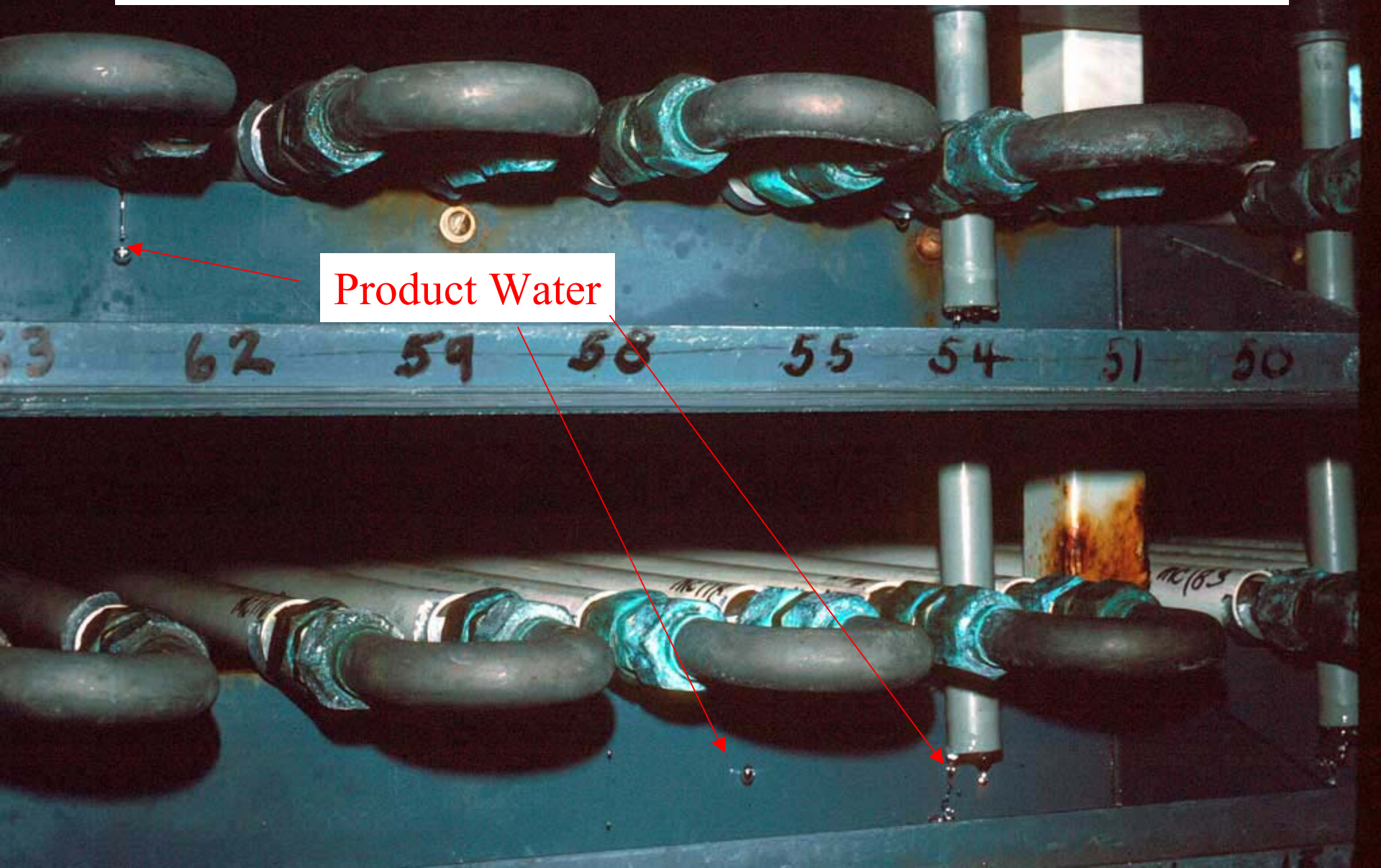
- Rarely used today due to low packing density
- Applications for special recovery, such as concentrating oil/water mixtures
- Applicable when intense fouling occurs
- Approach used for ceramic membranes in membrane bioreactors
- Full-scale applications in the 1960s for reducing TDS of groundwater in remote San Joaquin Valley towns

Tubular Schematic Diagram



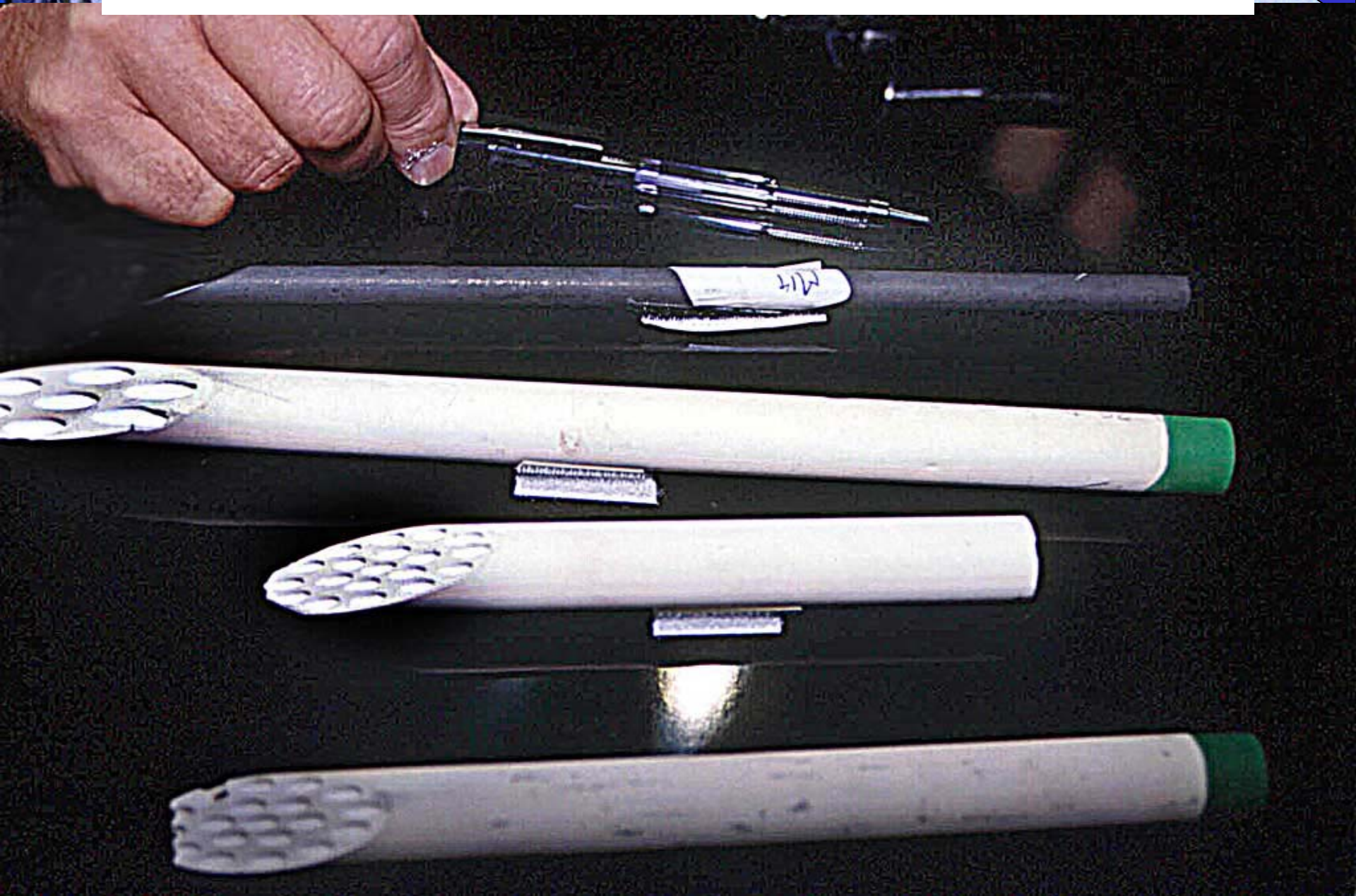
Tubular Membranes at Las Gallinas

End Connections and Product Recovery



Membrane End Connection

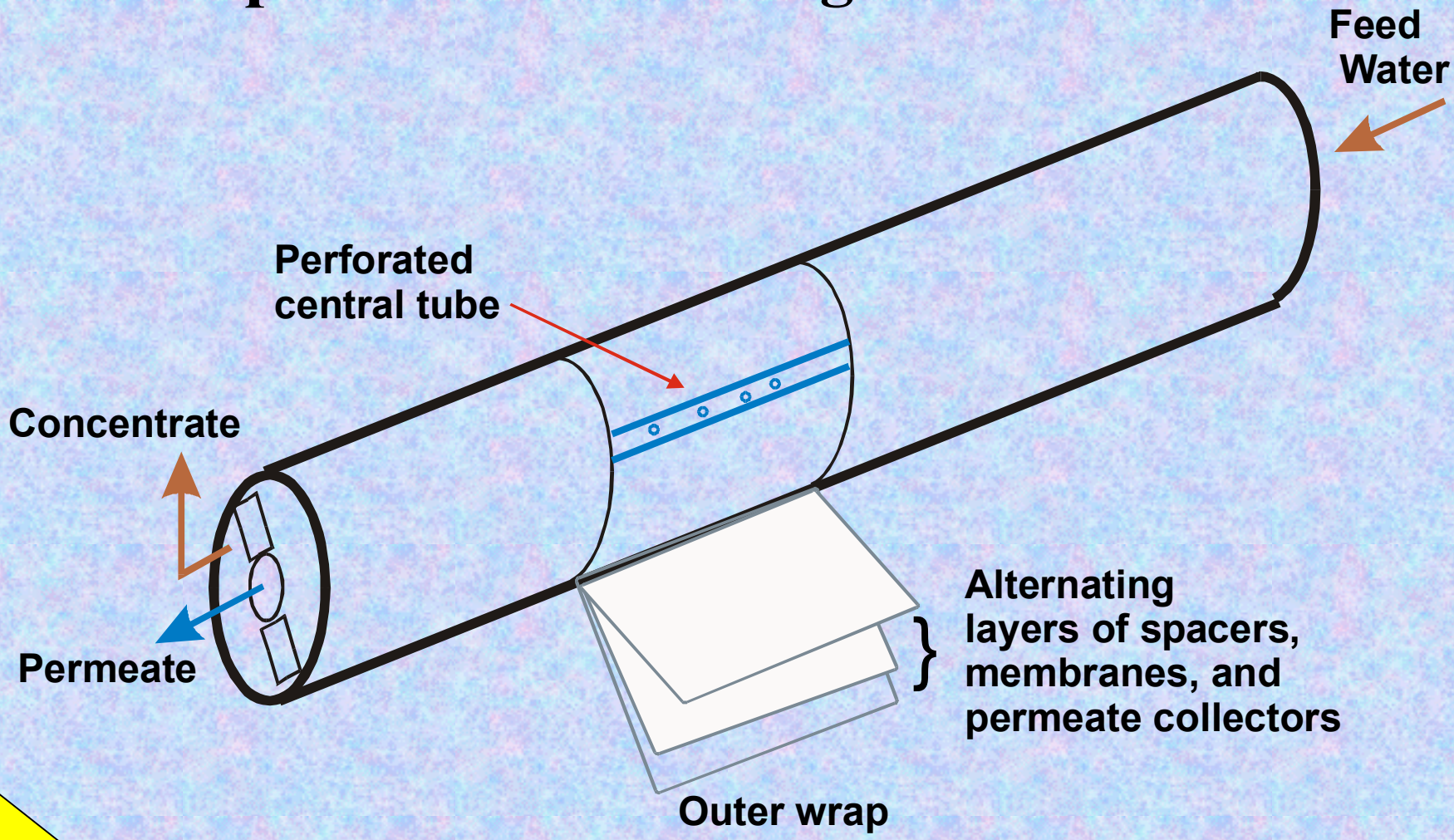
Ceramic Membranes



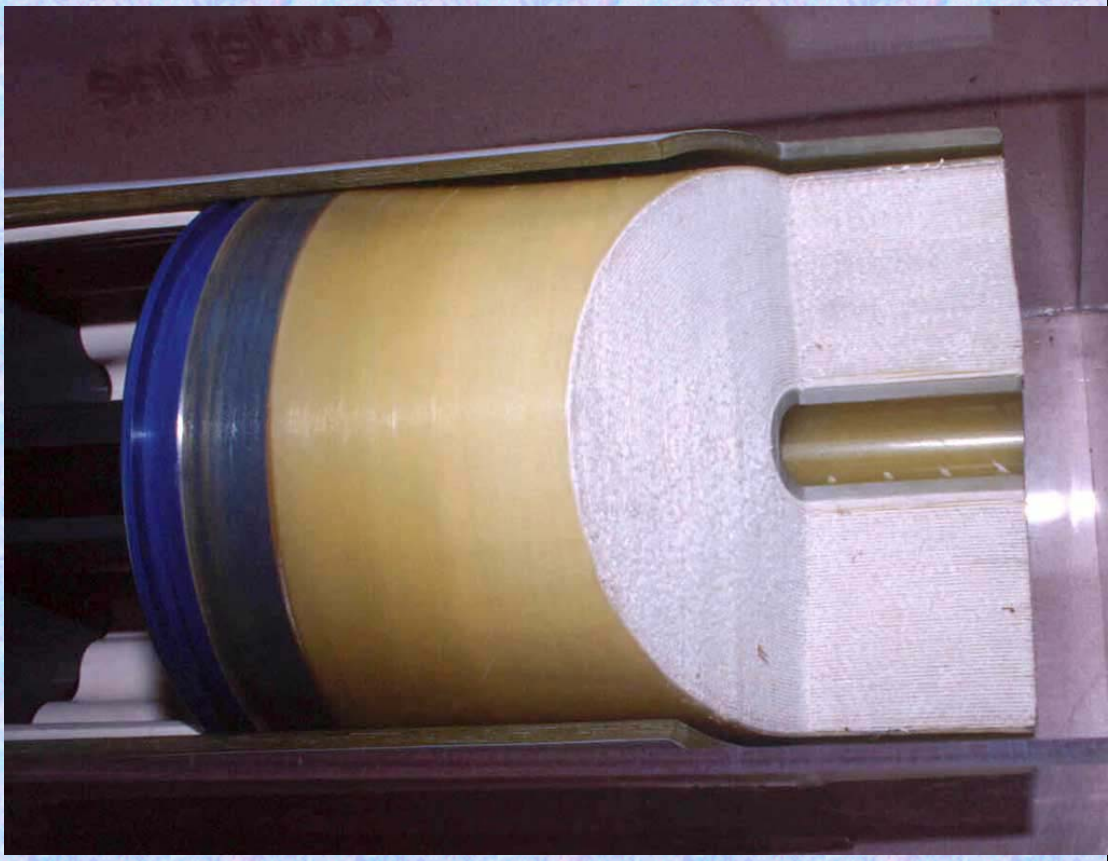
Spiral Wound Membranes

- High packing density
- Standard holders and configurations
- Many membrane alternatives (CA, thin-film composite, PA, etc.)
- RO, Nano and Ultra membranes available
- Some manufacturers make micro filters in spiral wound configurations
- Most common configuration in use today

Spiral Wound Configurations



Spiral wound cutouts



Commercial Installation, West Basin in Calif.

End Configuration

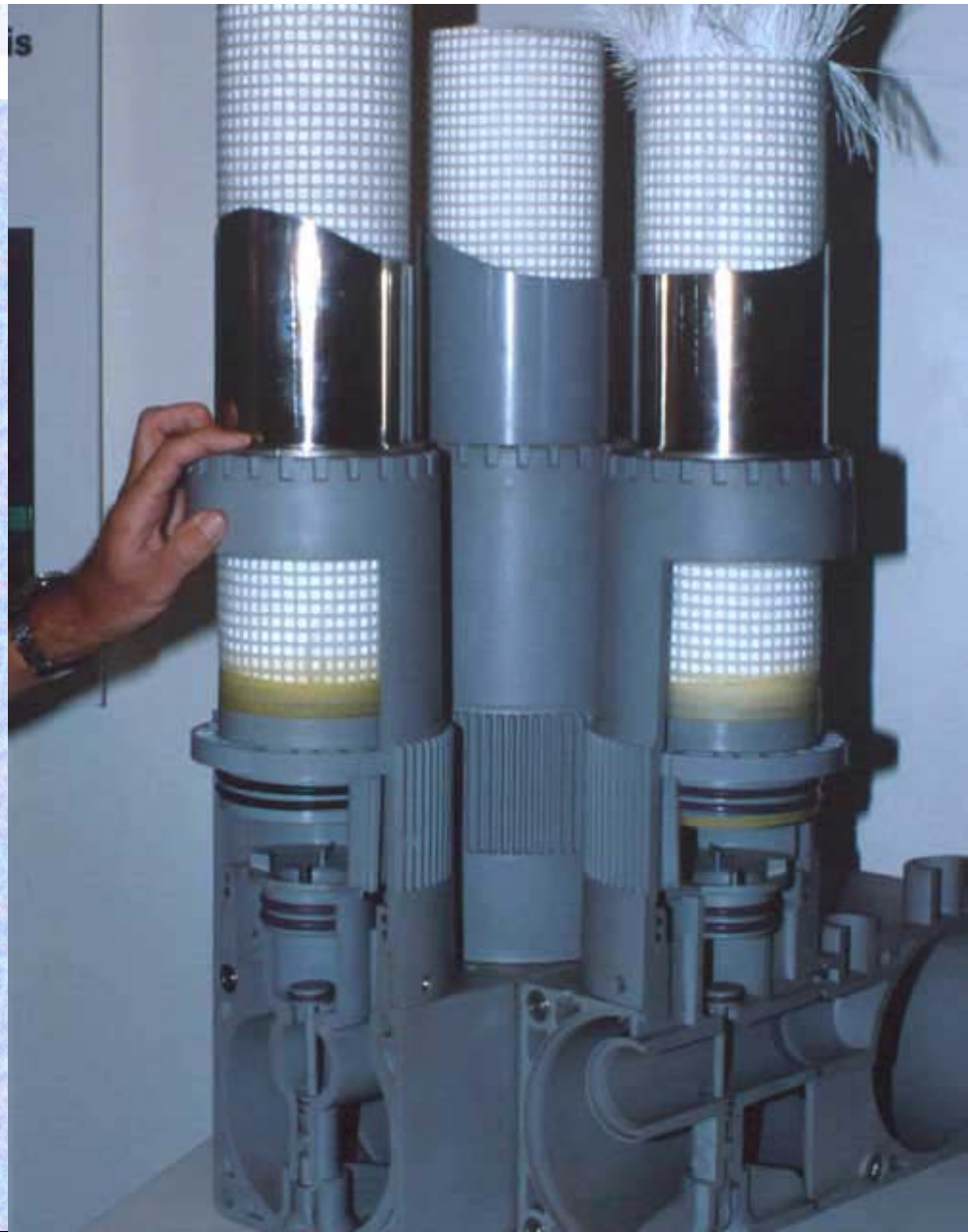
Hollow Fine Fiber

- Highest packing density
- Fewer membrane alternatives
- Requires high quality feed water
- Rarely found in water reclamation
- Exception - configuration used for the most successful micro filter, as of today.

Hollow Fine Fiber Bundles

Hollow Fine Fibers (Memcor Microfilter)

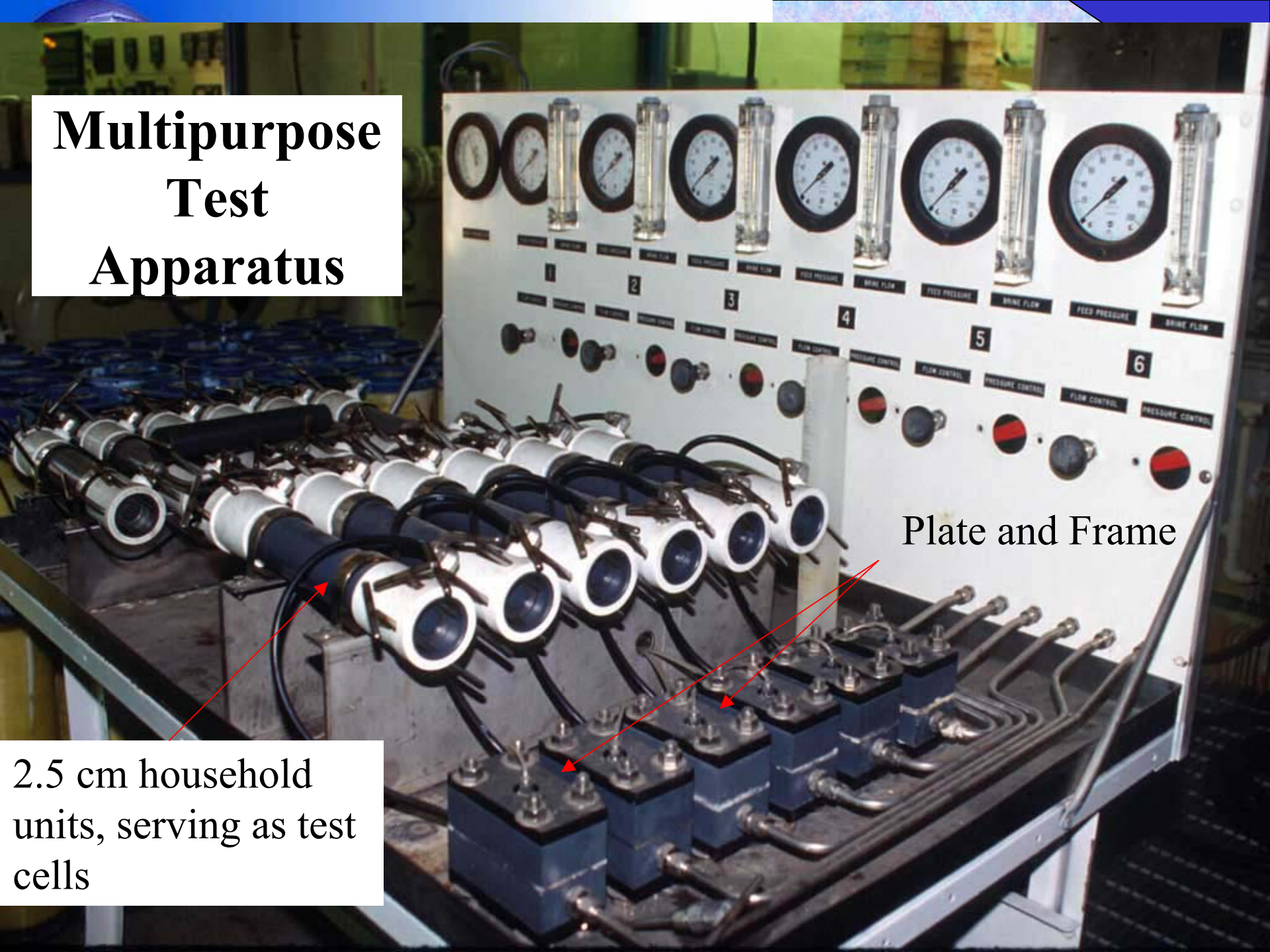
Multi-Membrane Cutouts



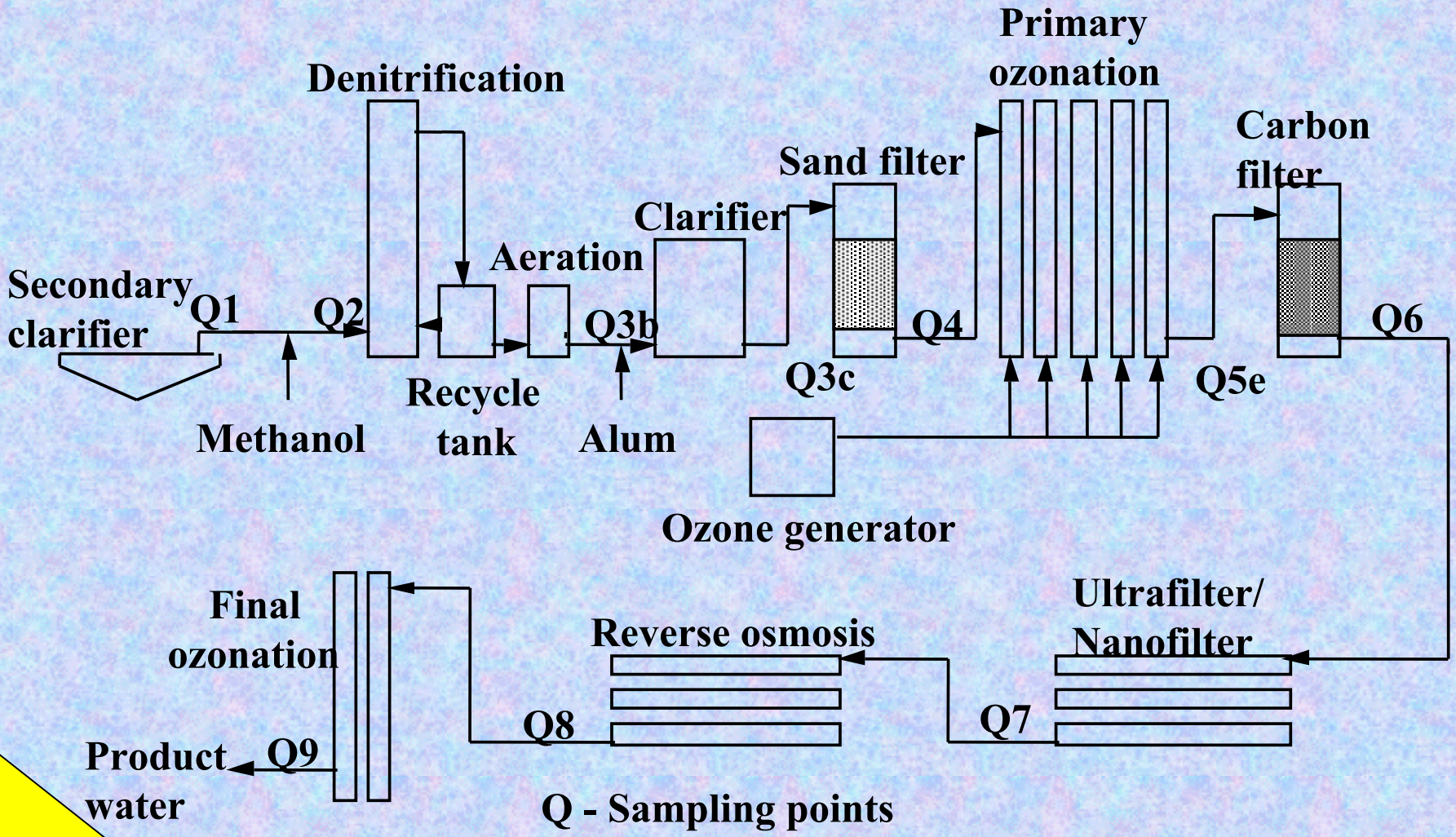
Pilot and Test Apparatus

- Pilot studies usually performed before full scale plants are constructed
- Small test cells used for initial work, theoretical studies and membrane development
- Larger cells and pilot plants using a small number of full scale membranes often used for process evaluation

Test Cells


Multipurpose Test Apparatus
Plate and Frame
2.5 cm household units, serving as test cells

Arrowhead Pilot Plant



Lake Arrowhead Pilot Plant

Some Results

Parameter	Sec. Effl.	Product	Units
pH	7.5 ± 0.4	6.3 ± 0.3	-
Alkalinity	78 ± 16	7.0 ± 3.0	mg/L
Hardness	90 ± 13	5.0 ± 2.0	mg/L
Turbidity	6.3 ± 2.8	< 0.1	NTU
TSS	12 ± 6.8	< 0.2	mg/L
Total Coliform	1.1×10^6	< 2.2	#/100 mL
E. Coli (Fecal)	-	< 2.2	#/100 mL
Streptococcus	-	< 2.2	#/100 mL

Applications

- MF – replacement of granular media filters
- MF - in water treatment plants, filter conventional backwash to prevent recycling protozoans
- NF, RO - primary treatment method in reclamation for higher uses, provides disinfection
- NF – water softening, phosphate removal
- RO – brackish water treatment
- RO – desalination – beginning to compete with distillation, especially for smaller plants
- RO – high quality water for semiconductors
- RO - pretreatment for ion exchangers

Pilot Tests

- Generally pilot tests of specific membranes for a specific application are recommended.
- The science is still has some “black art” aspects which can cause problems
- Manufacturers tend to have a wealth of unpublished but important data and results

Predictions

- Membranes will gradually replace a number of existing technologies, such as granular media filtration
- In reclamation plants in California, we have already seen RO replace high-lime coagulation, carbon adsorption, granular filtration, and reduce disinfection requirements.
- They easily fulfill the double barrier concept for water reclamation
- Research in membranes is “tricky.” Manufacturers have a lot of proprietary information, as well as control over the product. We will be moving from “open” technology to a “closed” technology as membranes are adopted for more applications

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