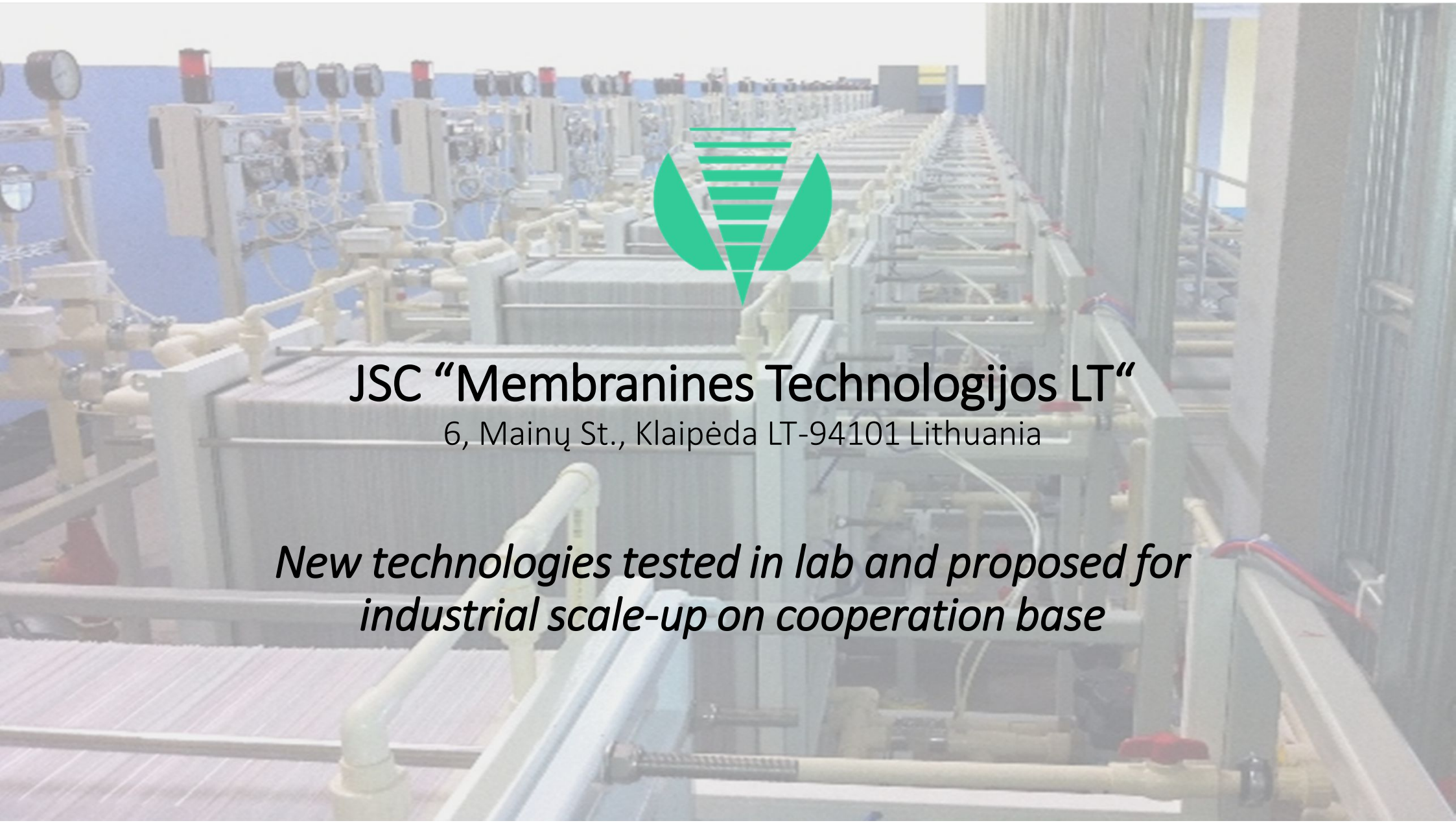

JSC “Membranines Technologijos LT“

6, Mainų St., Klaipėda LT-94101 Lithuania

New technologies tested in lab and proposed for industrial scale-up on cooperation base

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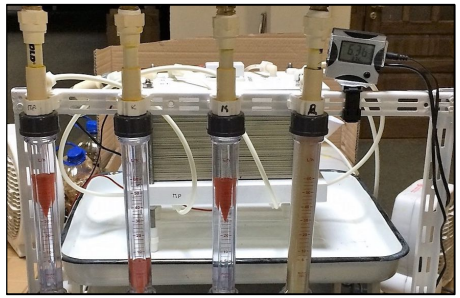
List of innovative technologies based on ED/EDBM

Having explored the practical and summarizing their own experience for processing different types of whey using electrodialysis, we developed several new technological solutions including new devices that differ from common electrodialysis system.

1. ED-EDBM technology. Reagent-free technology for acid milk whey processing.
2. ED-C technology for demineralization of concentrated acid and sweet whey without dilution in "one-pass" mode with applying the “warm process".
3. ED-T technology for demineralization of whey protein concentrates (delactosed whey) without additional dilution, in continuous mode, at higher temperature of solution.
4. ED-T technology for demineralization of chicory extract by reagent-free method in production of inulin.
5. ED-T technology for removal inorganic salts from gelatin in a continuous mode, without additional dilution, with higher temperature of solution.
6. Contactless ED-EDCA technology for the processing of acid whey.
7. DDE technology. Reagent-free alkali recovery from solutions with high content of alkali and salts.



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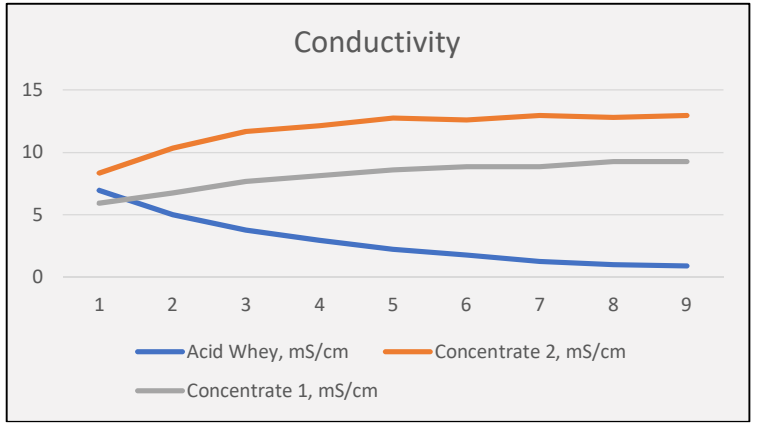
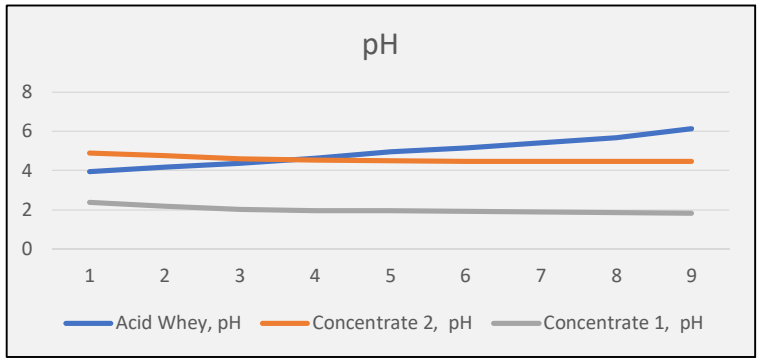
ED-EDBM: Reagent-free acid whey processing

The technology is based on unique combination of classical and bipolar electrodialysis. The main features and benefits of proposed solution are as follows:

- ✓ Process of demineralization and pH correction of acid whey occurs without the use of additional reagents.
- ✓ Processing is possible in the flow (single-pass) mode with a minimum holding time of whey in the equipment.
- ✓ Processing of whey is carried out at low pH which significantly reduces the loss of protein in the form of deposits on the membranes surface and consequently increases exploitation period of electromembrane parts, i.e. overall lifetime of the equipment.
- ✓ Ensuring the efficiency/maintenance of the proposed technology does not require the use of an additional significant amount of chemical reagents: alkali and acid are used only for CIP-washing.
- ✓ Reagents required for CIP-washing can be produced on the same process equipment from the respective salt and clean/demineralized water without purchase from third-party suppliers.
- ✓ Significantly reduced volume of salt concentrates to be disposed of: estimated 1 ton of discharged brine on 5-6 tons of products (ratio 1:5)
- ✓ The acid concentrate produced during processing is an aqueous solution of lactic acid, which can serve as an initial material for the production of valuable chemical products - calcium lactate and calcium tri-phosphate.





Dynamic of typical changes of conductivity and pH by ED-EDBM Technology processing acid whey TS 20%, product quality D90 (an example of actual data from Customer)

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ED-C: High efficient whey demineralization

- Whey demineralization by classical electrodialysis used at the present time can be improved by right set-up of parameters with positive influence on ED efficiency like feed concentration, temperature, current density, linear velocity and appropriate ED stack construction.
- Thanks to our experience with ED process and stack designing we can propose demineralization of pre-concentrated whey without dilution in real "one-pass" mode at “warm” temperature. At the same it is advisable to process more concentrated solutions of whey and feed the reagent directly into the technological pathway.
- Standard operation: Feed @ 24-28%TS; process temperature 20-25°C; continuous one-pass flow, product quality D70 (acid whey), D90 (sweet whey). This operation mode was successfully pilot tested on real whey at dairy plant in EU.
- Features and benefits:
  - ✓ Availability to work with more concentrated feed which is more suitable for ED process
  - ✓ Reduced holding time of product in process thus low risk of microbiology contamination
  - ✓ Lower energy consumption for pumping
  - ✓ Smaller foot-print thanks to our high efficient ED stacks

	Initial whey after NF (before ED)				Whey after ED-C				Salt concentrate after ED		
test #	dry matter (%)	ash (%)	ash in dry matter (%)	pH	dry matter (%)	ash (%)	ash in dry matter (%)	pH	dry matter (%)	ash (%)	ash in dry matter (%)
1 acid whey	24,80	2,20	8,87	4,74	19,20	0,48	2,50	6,02	3,50	1,94	55,43
2 acid whey	24,00	2,02	8,42	4,73	22,20	1,04	4,68	6,02	2,50	1,28	51,20
3 acid whey	23,80	2,00	8,40	4,67	21,90	0,85	3,88	6,01	2,40	1,23	51,25
4 sweet whey	26,90	1,50	5,58	5,76	25,60	0,51	1,99	6,01	1,40	0,76	54,29
5 sweet whey	26,50	1,48	5,58	5,71	26,50	0,58	2,19	6,00	1,80	0,90	50,00
6 sweet whey	26,80	1,44	5,37	5,95	25,50	0,35	1,37	6,04	2,60	1,13	43,46

Typical data by ED-C Technology processing acid and sweet whey (an example of actual data, analysis from Customer)

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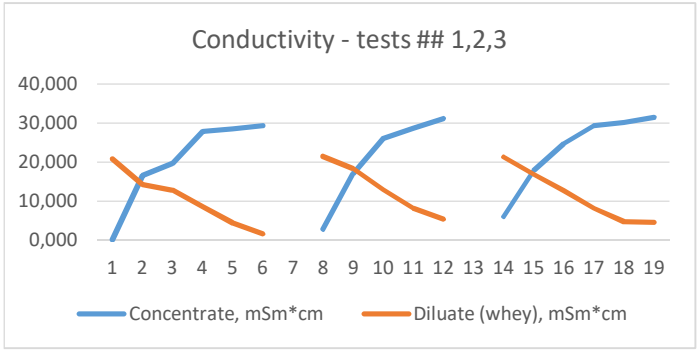
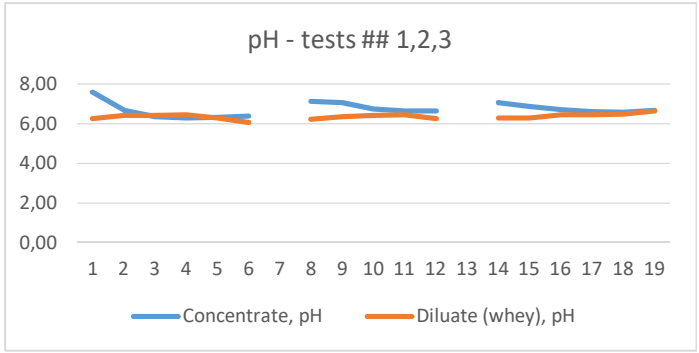
ED-T: Demineralization of concentrated whey protein solution at high temperature

- Demineralization of whey protein concentrates (delactosed whey) in a continuous mode without additional dilution at higher temperature of solution.
- The technology is based on a classical electrodialysis with use of our special ED stacks EMA-TMH type.
- Main features and benefits:
  - ✓ Processing of delactosed whey "as it is" @ TS>40% without additional dilution with water
  - ✓ Process temperature in the range of 50-60°C in order to maintain product viscosity
  - ✓ Short hold-up time of product in the system (less than 6 minutes)
  - ✓ Special ED stacks can be installed in series, 2 or 3 stages arrangement without intermediate tanks and additional pumps

Initial raw delactosed whey delivered by client for tests.





Dynamic of typical changes of conductivity and pH by ED-T Technology processing delactosed whey 40%DM (an example of actual data)

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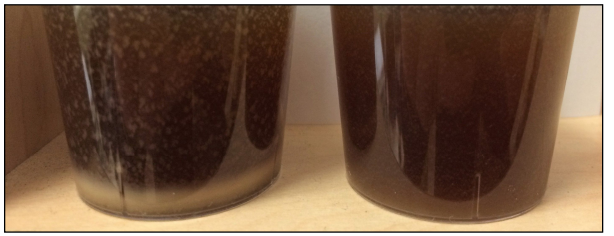
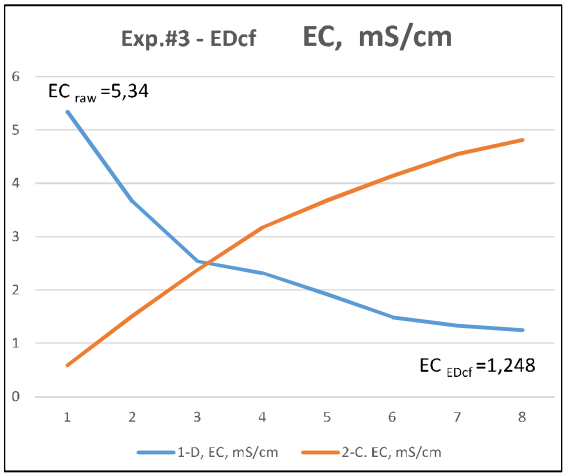
ED-T: Demineralization of chicory extract for inulin production

- Inulins are a group of naturally occurring polysaccharides produced by many types of plants, industrially most often extracted from chicory. The inulins belong to a class of dietary fibers known as fructans.
- Demineralization is one part of inulin extraction process from chicory roots. Usually ion-exchange technology is used to remove the salts from the inulin.
- Several ED tests with different membranes and arrangements have been carried out on real chicory solution with aim to achieve lowest possible desalination level and check feasibility of ED process.
- Typical process figures
  - START: °Bx_{start} = 10.1, C_{start} = 5.34 mS/cm, pH_{start} = 4.97, $time_{start}$ = 12:20
  - END:°Bx_{end} = 9.4, C_{end} = 1.248 mS/cm, pH_{end} = 2.87, $time_{end}$ = 14:05
  - Process temperature: 18-65°C
  - Conductivity cut: 76.63%
- Observations during trials
  - Chicory extract can be easily demineralized by electrodialysis, no any problems occurred during trials.
  - Only simple mechanical filtration as ED pre-treatment is required.
- Samples of ED outputs after the trial, diluate (product) and brine (effluent) were sent to the client for detail laboratory analysis and mass-balance including determination of losses.



Picture of samples delivered for trial. Due to sedimentation of undissolved solids mechanical filtration (1 micron) has been performed before desalination test on electrodialysis.



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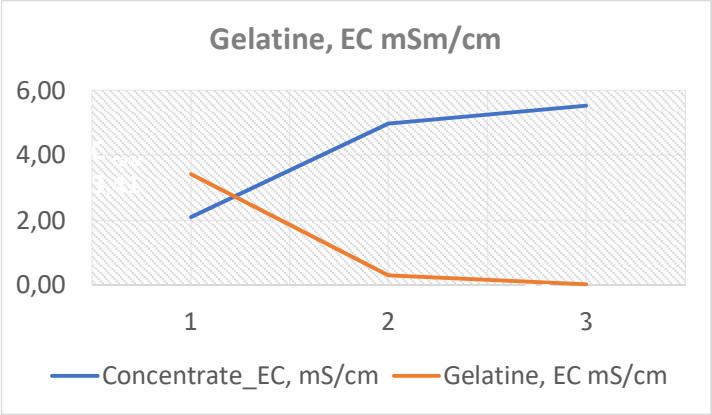
ED-T: Removal of inorganic salts from gelatine

- Gelatine is a natural collagen protein, mixture of peptides and proteins produced by partial hydrolysis of collagen extracted from the skin, bones, and connective tissues of animals such as domesticated cattle, chicken, pigs, and fish.
- Currently demineralization by ion-exchange is part of gelatin purification.
- We did several laboratory ED tests for one prospect with aim to check feasibility of ED process.
- Typical process figures for feed TS 21% (after UF)
  - START: C_{start} = 3.41 mS/cm, pH_{start} = 3.9
  - END: C_{end} = 0,139 mS/cm, pH_{end} = 7.35
  - Process temperature: 53-55°C
  - Conductivity cut: 96%
- Observations during trials
  - We did not face any problems during gelatine processing. Operating temperature, concentration and viscosity are acceptable for our equipment.
  - Obviously, ED on gelatin should work in a single-pass continuous mode at a constant temperature of at least 50°C with minimal maintenance stops.
- Samples of ED outputs after the trial were sent to the client for detail laboratory analysis and mass-balance including determination of losses.

Pre-filtered and demineralized gelatine



Conductivity change during processing of pork gelatine TS 21%

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DDE: Reagent-free alkali recovery from solutions with high content of alkali and salts

- DDE is energy-efficient, environmentally friendly, reagent-free technology for recovery of pure alkali from various process solutions and industrial wastewater.
- DDE technology is successfully used also for removing excess alkali in the processes of correction pH, e.g. pharmacy, food and biotechnology.
- Selective extraction of the alkali is carried out in special electrodialysis module called electromembrane diffusion-dialysis extractor developed by our company.
- As a result of diffusion-dialysis processing pure alkali is recovered from aqueous solutions, then further concentrated in electromembrane concentrator module and returned to reuse
- DDE technology can be used in various applications mainly with goals as follows:
  - ✓ to decrease impact of some technological processes on the environment;
  - ✓ to reduce operating costs, energy consumption and consumption of reagents;
  - ✓ to minimize quantity of discharged alkali-containing wastewater or fully neutralize them;
  - ✓ to get additionally valuable commercial product - concentrated pure alkali for re-use.

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DDE: Success story (power stations)

- First DDE project was realized in 2009-2011 in Kazan Power Station, Russia.
  - Feed alkali-containing (5.2 g/l NaOH) purge water from evaporator plant.
  - Pure alkali separated by DDE is further concentrated by electromembrane-concentrator up to 4-4.5%ww NaOH.
  - Concentrated alkali solution is re-used for regeneration of ion-exchange.
  - In 2016 DDE plant was modernized for increasing capacity in 2 times.
- Actually similar DDE project is under commissioning at Nizhnekamsk Power Station (Tatarstan).

DDE Plant. Kazan, 2011

Color of solutions

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DDE: Success story (hydrometallurgy)

- Our company did lab tests of DDE on real technological solution from Russian hydrometallurgy plant processing of tungstate sodium.
- Inlet to DDE was initial technological solution tungstate sodium with high alkali content (NaOH up to 150 g/l, Na_2WO_4 up to 180 g/l).
- Client's requirement was to recover min. 50-55% of NaOH from initial solution and get pure alkali with concentration min. 100 g/l for reuse.
- Obtained results:
  - DDE technology achieved high stability of alkali recovery in range 75-85%
  - Max. concentration of extracted alkali reached at membrane-concentrator was 244 g/l
  - We determined optimal level of alkali concentration for this case at 120-140 g/l for reason of minimizing energy consumption in concentration step (1.17-1.9 kW/kg NaOH 100%).
- We have developed an industrial process flowchart, equipment placement in the production building (PFD and PID schemes) and full specification of equipment in accordance to client's order.

Thank you for your attention!

UAB Membraninės Technologijos LT
JSC Membranines Technologijos LT

Mainu St., 6, Klaipeda, LT-94101, Lithuania
phone +370 68049076
skype: membranines
e-mail: membrane@mtlt.lt
Web: www.mtlt.lt