Status of Palmachim Desalination Project

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Introduction

Palmachim desalination project is a seawater RO desalination plant of 30 million cubic meters per year nominal capacity. The project, which in these days enters the first stage of wet commissioning, is located at Palmachim Industry Park, at a distance of 500 meter from Palmachim beach. The project is a BOO type project for 25 years and is the second large SW desalination plant in a series of Public Private Partnership projects promoted by the government of Israel in order to bring the national seawater desalination capacity to 400 million cubic meters per year.

The first part of this paper describes the organizational aspects of the project and its current status. The second part provides a technical overview of the project with a special focus on aspects of boron removal and biofouling abatement which are unique to this project.

Project Structure and Time Table

Via Maris Desalination Ltd is a special purpose company which has been incorporated in 2002, after its bid for the supply of 30 million m³/year of desalted seawater at Palmachim, has been accepted.

The project is a government concession for 25 years to build own and operate a sea water desalination facility which is capable of providing to the WDA (Water Desalination Authority) an amount of 30 million cubic meters annually.

Via Maris is owned by a group of Israeli investment and engineering companies, among which are: Granit Hacarmel – 26.5%; Tahal- 26.5%; Ocif – 21%; Middle East pipes -21%; Oceana – 5%.

To implement the project, Via Maris Desalination formed two organs, one for EPC and one for O&M, both owned by the SPC partners. The EPC tasks were undertaken by Via Maris Desalination Construction Partnership, which does in house all the procurement tasks. The general engineering design tasks were subcontracted to Tahal, while the process engineering tasks to G.E.S Ltd, formerly Tambour Ecology Ltd, of Granit Hacarmel Group. Marine works, civil works, mechanical works and electrical works were sub contracted by VDCP to local firms. The O&M contractor is Via Maris Operations Ltd which subcontracts this task to G.E.S Ltd.

The main project milestones are:

October 2002 - BOO agreement was signed.
August 2004 - Building permit for earth works obtained
November 2004 - Building permits for the main installation, transformation station and land works for intake and out fall pipes obtained.
February 2005 - BOO Amendment agreement and financing agreements were signed with an effective date of 1.1.2005.
May 2005 - Building Permits for the marine works (conditional for financing cash flow) was obtained.
May 2005 - Commencement of major civil and marine works.
April 2006 - Submergence of the marine pipes completed.
May 2006- Commencement of piping and electromechanical works.
November 2006- Transformation station completed and connected to IEC grid.
November 2006- Intake and outfall pipelines connections completed, seawater reach the inland SW lift station.
November 2006- Commissioning of the pretreatment section starts.

Picture 1: Palmachim Desalination Plant, April 2006

Plant Design Basis

- Raw water source is east Mediterranean surface sea water, extracted by a submerged suction head at a distance of 1,300 m off shore, from a depth of 10 meters below the surface of the sea and 4 meters above the sea bed.
- Sea water salinity is 39.1 ppt (gram salt per kg seawater). Sea water design temperature range is 16 to 30 degrees centigrade.
- The aggregated delivery of the plant, which is by contract 30,000,000 m³/y, is divided into 6 bi monthly quotas which follow the nations seasonal demand curve. Winter deliveries are 85% of the average while summer deliveries are 115% of it. The maximal instantaneous production rates of the plant were designed to be 118% of the summer quota and up to 138% of the winter quota to exploit low power tariffs on nighttime, weekends and holidays. Great savings are obtained by operating the plant at peak production when on low tariff nighttime, and on reduced production rate when on high tariff daytime. By conventional definitions the plant rated capacity at 30°C is 4,660m³/h or 40,800,000m³/y. At 16°C it is 4,060m³/h and 35,500,000m³/y.
- Product water specifications

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Process Overview

- **Raw water source:** In plant lift station connected by an inland concrete pipe to a coastal junction well which connects by HDPE pipe to a submerged intake structure at a distance of 1300 meters off shore.
- **Seawater Pretreatment:** "Classical" coagulation, flocculation followed by a dual media filtration. Optional pH elevation in summer.
- **Pass 1, seawater Desalination:** 6 trains, with Pelton wheel type turbines for energy recovery. Permeate is withdrawn from both ends at a flexible and controllable ratio which depends on the seasonal operation results. Front end cut designed to be between 25 to 50 percent according to season.
- **Permeate Pretreatment:** Unique ion exchange softening using pass 2 brine as a regenerant. Feed pH is raised to 10.5.
- **Permeate desalination:** 98% recovery 4 stage second pass with 2 brackish water type stages followed by 2 seawater type stages.
- **Post treatment:** Rehardening by dissolution of calcite by sulfuric acid and chlorination.

**Boron Removal Aspects**

*The Motivation for Boron Removal*

The adverse effects caused by the presence of high boron concentrations in irrigation water, has been recognized by agronomists many years ago. Before year 1993 limits for boron concentration in drinking water were not dealt by any of the standards. Back in 1993 the world health organization – WHO - issued a guideline limit for boron in drinking water which was set at 0.3 mg/l. This act was triggered by research works indicating risks for male fertility by high boron concentrations in potable water. In 1998 the WHO issued an addendum to the guide line which increased the limit to 0.5 and defined it as **provisional** “because with treatment techniques available, the guideline value will be difficult to achieve”.

![Figure 1: Process scheme](image-url)
Israel first experienced the damage inflicted to sensitive crops by an integrated potable / irrigation water system at Eilat, when the first SWRO plant, which was not designed for boron removal, went on line. This led the Israeli water authorities to become the first nation to specify a boron limit of 0.4 mg/l for its first generation of massive RO desalination plants, Ashkelon, Palmachim and Shomrate. The limit for the second generation has already been reduced to 0.3 mg/l.

Israel water desalination authority, in an attempt to use massive desalination also as a lever for lifting the overall nation wide water quality, offered price bonuses for low chloride levels. This "salinity bonus level" was set at 70 mg/l for Palmachim and at 20 mg/l for Hadera bid.

**Overview of Boron Removal Methods**

- Membrane based methods: These are preferable for designs targeted to achieve simultaneously low boron and low TDS. All membrane methods are based on an alkaline second pass to enhance boric acid dissociation into borate ion.
- The limiting Factor: Magnesium hydroxide low Ksp (1.8E-11) limits high recovery or high pH of an alkaline second pass.
- Common Solutions: Moderate pH (10.0) moderate recovery second pass followed by an acidic 3rd pass that treats the brine of the 2nd pass. The third pass acts primarily as a softener for magnesium removal. The permeate of the 3rd pass is treated by an alkaline 4th pass.
- High recovery second pass, reportedly 95%, employing tested anti-scalants.
- Where reduced TDS is not an issue, boron selective ion exchangers can be employed for boron removal from a first pass permeate directly, or from the brine of the second pass.

**The Innovative Ion exchange Softening Method**

- As the limiting factor for boron reduction is the magnesium hardness, the outright solution appears to be ion exchange softening.
- The limitations of generic IX Softening are:
  - Regenerant Cost: Good quality regeneration salt is too costly.
  - Seawater which is a practically costless regenerant are commonly used by many seaside softening systems in industry and commerce. Sea water unfortunately contains nearly 1500 mg/l of magnesium which is OK for 99% of the commercial softening plants, but can not produce the ultra low magnesium leakage effluent that a high pH / high recovery second pass requires.
- The Supper Regenerant – Pass 2 brine
  - Superior Quality: Being produced from ultra low hardness feed water its hardness content at 3% strength is approximately 0.001% of the TDS. This low value is by far better than any regenerant available commercially. The typical hardness content of a high quality commercial regeneration salt is 1% which is 1000 times worth.
  - Ample Quantity: It is available in ample quantities! The sodium chloride content of the brine stream is 600% to 900% of the equivalent hardness content of the feed stream which undergoes softening. In common commercial IX softening, the equivalents ratios of sodium chloride to hardness are between 130% for the best economically efficient operations to 300% for the most waste full ones.
  - Free of Charge: The price of pass 3 brine is Zero!!! It must be disposed of anyhow.
• The ultra low hardness effluent obtained by the ion exchange softening system allows for a pH increase of the feed to second pass to a level which permits a one pass boron reduction operation.

![Figure 2: Boron removal techniques](image)

**Biofouling Abatement Measures**

(Growth Retarding & Biofilm Removal Techniques)

Automated procedures to retard bio film growth on the seawater membranes and affect its removal, are built into the plant design and its automatic control system. These include:

- **Enhanced Osmotic Backwash:** The procedure involves a prolonged osmotic backwash (direct osmosis) when a train is stopped. The osmotic backwash effect is induced by operating the booster pump at low pressure for a prolonged period, in order to displace the diluted seawater / brine from the feed/ brine channels after the main high pressure pump has been stopped. All this time fresh permeate is provided from the elevated front end permeate tank.

- **Reverse Entry Cleaning Procedures:** The flow pattern inside a spiral wound module is a major drawback of this most popular module design. The brine seal, which forces the feed into the element flow channels, creates an annular cavity which is 1.5 mm wide and 1000mm long in between the pressure vessels and the elements. This annular cavity is totally stagnant and serves as induction area for scaling. At the same time it provides a friendly environment for bio film growth. Once fouled it is very difficult for CIP reagents or biocides to penetrate this cavity by recycling them in the normal service flow pattern. At Palmachim the CIP and
permeate flush systems are integrated and connect to the RO trains in an opposite manner to the feed connections. Permeate once through flushes and CIP recirculation solutions enter the modules from the brine ends and exit at the feed end. This forces the brine seals to yield and allow permeate flushing, cleaning and disinfection solutions to their job inside this otherwise inaccessible annular cavity.

**Figure 3**: Enhanced Osmotic Backwash

**Figure 4**: Clean In Place technique