Case Study – Steel Mill Water Recycle

Project Background

Plant Type/Location: Steel strip mill in central U.S. engaging in steel rolling, skiving and plating operations.

Project Objective: Improve compliance consistency, reduce sludge disposal expenses, and recycle water to lower ion exchange regeneration cost.

Year Installed: 2012

Average Flow: 200 GPM (45 m^3/hr)

Treatment Concept: The treatment process starts with flow equalization, caustic precipitation and Duraflow Membrane Filtration (DMF) followed by Reverse Osmosis (RO). The RO permeate is returned to the on-site reservoir for reuse as rinse water in the production process, and the RO reject stream is directed to an NPDES permitted discharge or to the city POTW.

Major Contaminants: Nickel, Copper, Iron, Cobalt and Zinc.

Membrane Precipitation Process

Chemical Softening: Reaction I – Caustic soda to pH 9.3   (metals precipitation)

Reaction II - Aluminum coagulant   (coagulation of colloids)

Concentration Tank - Activated carbon   (adsorption of organics)

Duraflow Filtration: The DF membranes are manufactured in a tubular configuration designed to handle high solid concentration as illustrated in Figure 1. The membranes, made of PVDF, are cast on the surface of porous polymeric tubes to produce a nominal pore size of 0.1 micron. Bleach, Peroxide, Sulfuric Acid or Hydrochloric Acid are typically used for membrane cleaning.
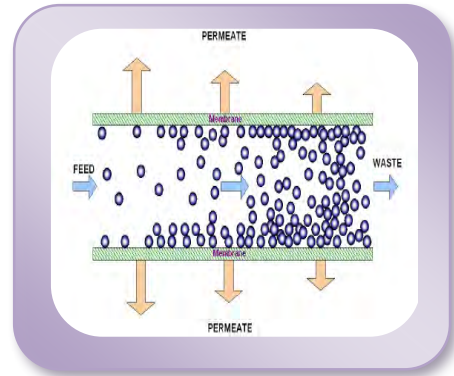
| Figure 1 – DF Membrane Module | Figure 2 – DF Crossflow Filtration |

The chemically pre-treated wastewater is processed through the DF membrane modules designed for separation of the precipitates from water. The wastewater is pumped at a velocity of 12 – 15 ft/sec through the membrane modules (Figure 2) connected in series. The turbulent flow, parallel to the membrane surface, produces a high-shear scrubbing action which minimizes deposition of solids on the membrane surface. During operation, filtrate permeates through the membrane, while the suspended solids retained in the re-circulation loop are periodically purged for further de-watering. An automatic back-pulse mechanism is an integral part of the operation design to provide physical surface cleaning by periodically reversing the filtrate flow direction. The DF has been operated with an average flux of >400 GFD. The entire treatment process is schematically depicted in Figure 5.

DF Membrane Module Specifications

DF Membrane Module Specifications	
Flow configuration	Cross-flow
No. of tubes per module	10
Dimensions	6" (15 cm) dia. x 72" (183 cm) long
Tube diameter	1" (2.5 cm)
Membrane area per module	15 ft^2 (1.40 M^2)
Shell construction	Schedule 40 PVC
Membrane material	PVDF
Nominal pore size	0.1 micron
Module weight	40 lbs (18.2 kg)

DF Membrane Equipment Configuration

See Figure 3 and 4 for physical equipment arrangement.

DF Membrane System Configuration	
No. of DF modules (total)	96
No. of skids (total)	2
No. of DF modules / skid	48
No. of Trains / skid	3
No. of DF modules / Train	16
No. of skids in service mode	1
No. of skids in standby mode	1

Key DF System Operation Data

DF System Operating Data	
No. of modules per train	18
Max Operating inlet pressure	60 PSI (3.5 Kg/CM^2)
Operating temperature	<105°F (41^{0}C)
Operating TSS in Conc. Tank	2 to 3 % (wt.)
Feed flow velocity	15 Ft/Sec (4.5 M/Sec)
Feed flow per train	350 GPM (80 M^3/Hr)
Membrane flux (average)	>400 GFD (680 LMH)
Back-pulse frequency/duration	20 Min / 10 Sec
Back-pulse volume/module	1.5 – 3.0 GPH (6 – 12 LPH)
DF module cleaning frequency	3-4 days
DF modules replacement	5 - 6 Years
RO module cleaning frequency	5 - 6 Months
RO modules replacement	4 – 5 Years
Service cycle	24 hrs/day 7 days/week

Key Performance Data

The removal efficiency for the contaminants of concern is presented as follow:

Contaminants	Influent (CTB) (mg/L as ion)	DF Filtrate (mg/L as ion)	RO Permeate (mg/L as ion)
Ni	50 - 200	0.05	<0.02
Cu	0.2 - 0.3	<0.1	BDL
Pb	0.3 - 0.8	0.01-0.02	<0.02
Zn	50 - 125	0.01 - 0.05	<0.01
Cr	0.9 - 1.4	0.02 - 0.03	----
COD	100 - 200	60 - 90	<5.0
TSS	250	2 - 3	ND
pH	2 - 11 S.U.	9.3 S.U.	6.5 S.U.
SDI	>Max. SDI Test Value	<3.0	----
NTU	Very High	<1.0	<0.5

DF Membrane System Pictures

Figure 3 – DF Membrane System

Figure 4 – Reverse Osmosis System

Figure 5: Steel Mill Wastewater Recycle

Process Flow Diagram

NaOH

Coagulant

Steel Mill Operations → Raw Wastewater 200 GPM → EQ Tank 70,000 Gal → Reaction 1 Tank 8,000 Gal → Reaction 2 Tank 8,000 Gal → Concentration Tank 12,000 Gal

Recycle Water to Plant Operations

Recycle Water Tank 500,000 Gal

Anti-Scalant

HCl

GAC Filtration I

GAC Filtration II

DF Membrane Filtration I 48 DMF Modules

DF Membrane Filtration II 48 DMF Modules

RO Feed Tank 2,000 Gal

RO Permeate 155 GPM

Reverse Osmosis (RO) I

Reverse Osmosis (RO) II

FP Filtrate to Reaction I Tank

Filter Press (30 Ft^3)

Sludge Thickening Tank 5,000 Gal

RO Brine Discharge 45 GPM

Sludge Cake (Disposal)