Wastewater Reuse in a Wastewater-Free Production Plant

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1 Introduction

1.1 Tire Market

While rubber products are virtually used in all industries, the dominant market is automotive. Other important markets include conveyor belts, roll flooring and personal products./5/ 2008 the global market has absorbed 1.1 billion passenger car and light truck tires./4/ Additionally, bicycle, motorcycle, aircraft and tires for special usage are fabricated. Recent tire factories are located in regions of low work and energy costs and close to the growing markets in Eastern Europe, Latin America and Asia. Thus, insights from tire projects are valuable for related and industries and those with high cooling water demand.

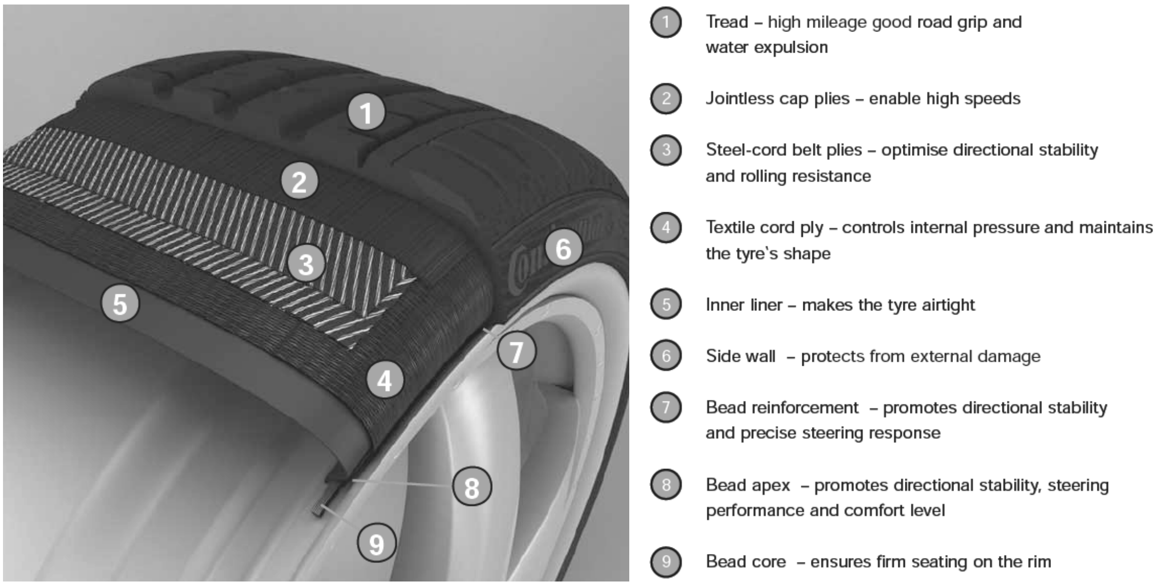
1.2 Project Background

German Continental AG is one of the largest automotive suppliers. The tires division develops and manufactures tires for cars, vans, light trucks, motorcycle and bicycles./1/ 2007 the company decided to strengthen its local presence in China and to build a new greenfield tire manufacture in Hefei, some 450 km west of Shanghai. The initial stage was for 4.25 million car tires per year – approx. 34 Gg - and planning was for more than 10 million car tires per year and tires for trucks and bicycles.

2 Tire Manufacture

2.1 Tire Engineering

Modern passenger car tires are made of up to 25 different structural parts and as many as 12 different rubber compounds. The main structural elements are the casing and the tread/belt assembly. The casing cushions the tire and contains the required volume of air. In fact, the air is the load carrier, not the tire. Most manufacturers produce only radial – or belted – tires for passenger car tires. The cords run perpendicular to the direction of travel and viewed from the side radially - giving the tire its name. The belt comprises several layers of steel belt plies and provides support and stability to the tread. To provide sufficient strength, the cords must be supported or complemented by other structural elements./2/



① Tread – high mileage good road grip and water expulsion
② Jointless cap plies – enable high speeds
③ Steel-cord belt plies – optimise directional stability and rolling resistance
④ Textile cord ply – controls internal pressure and maintains the tyre`s shape
⑤ Inner liner – makes the tyre airtight
⑥ Side wall – protects from external damage
⑦ Bead reinforcement – promotes directional stability and precise steering response
⑧ Bead apex – promotes directional stability, steering performance and comfort level
⑨ Bead core – ensures firm seating on the rim

Figure 1: Modern radial tire, courtesy of Continental/2/

The different tire components contain ingredients of variable amount. The basic materials are natural and synthetic rubbers and fillers, which contribute ¾ of the tire ingredients. Others are textile, steel wires, carbon black and chemicals.

2.2 Tire Manufacture Process

After supply and control of raw products, rubbers are sectioned, cut in portions, weighted and mixed in Banbury or internal mixers. There solid rubber is transformed to a kneadable material. The high energy absorption, temperature increase of 150 to 180 K within a few minutes, requires cooling. The hot material is then shaped by means of a screw-type extruder.

Calendering is the process of smoothing and compressing a material during production by passing a single continuous sheet through a number of pairs of heated rolls./6/ In tire manufacture multiple calenders are applied. The steel cord is embedded in one or more layers of rubber. To manufacture textile cord ply, textile threads are fed into the calendar, where they are embedded in a thin layer of rubber. Another calender forms the airtight inner liner.

Parts are assembled (built) together on the tire building machine. The readily built tire, known as “green tire”, is still plastic at ambient conditions. Sulfuric fluids are spray applied, that support the chemical process of vulcanization.

As final step, heat and pressure are applied to change rubber’s physical properties to higher tensile strength and to elastic (vulcanization). Automatic manufacture process requires alternate application of compressed air to tighten the bladder of the press to the inner tire surface, steam for heating of the outside tire moulds and the inside bladder, condensate to be extracted, vacuum for complete extraction of condensate, and to contract the inner bladder to withdraw the finished tire. Curing of the finished tire leads to final vulcanization.

3 Hydraulic System

3.1 Cooling Towers

To control temperature and avoid excessive heating of equipment and rubber, mixers, extruders and calenders are cooled with process cooling water at 20 to 25°C supply temperature. 30°C warm return flow is cooled back by means of cooling towers and water chillers during summer time. For HVAC systems water chillers are applied. Condenser water from chillers is cooled back in cooling towers.

Evaporation cooling towers are common and allow cooling of the circulating water near the wet-bulb air temperature. Due to the high volume of air passing through the towers, most air contaminants end up in the cooling tower water basin and as evaporation occurs the contents of salts increase. When the concentration of mineral salts exceeds their solubility, scale formation on heat exchange surfaces may occur. To prevent scaling on surfaces, part of the circulating water is removed from the system (blowdown), and replaced with fresh makeup water. To prevent fouling from biodegradable constituents, side stream filters are common to control solids and organic matters. Chemicals are added for corrosion protection, microbiological control and to increase solubility of salts. Water cycles numerous times before saturated and discharged. Generally maximum economic cycles are controlled by the calcium carbonate saturation index (SI) of the cycled makeup water./9/ Silica concentrations frequently limit the cycles of concentration./11/ Environmental requirements, insufficient amounts of fresh makeup water, and “green building” programs are forces driving to higher cycles. Installations operating with 17 cycles are reported./9/ Blowdown and sidestream filter backwash water is conventioally discharged to the wastewater system.

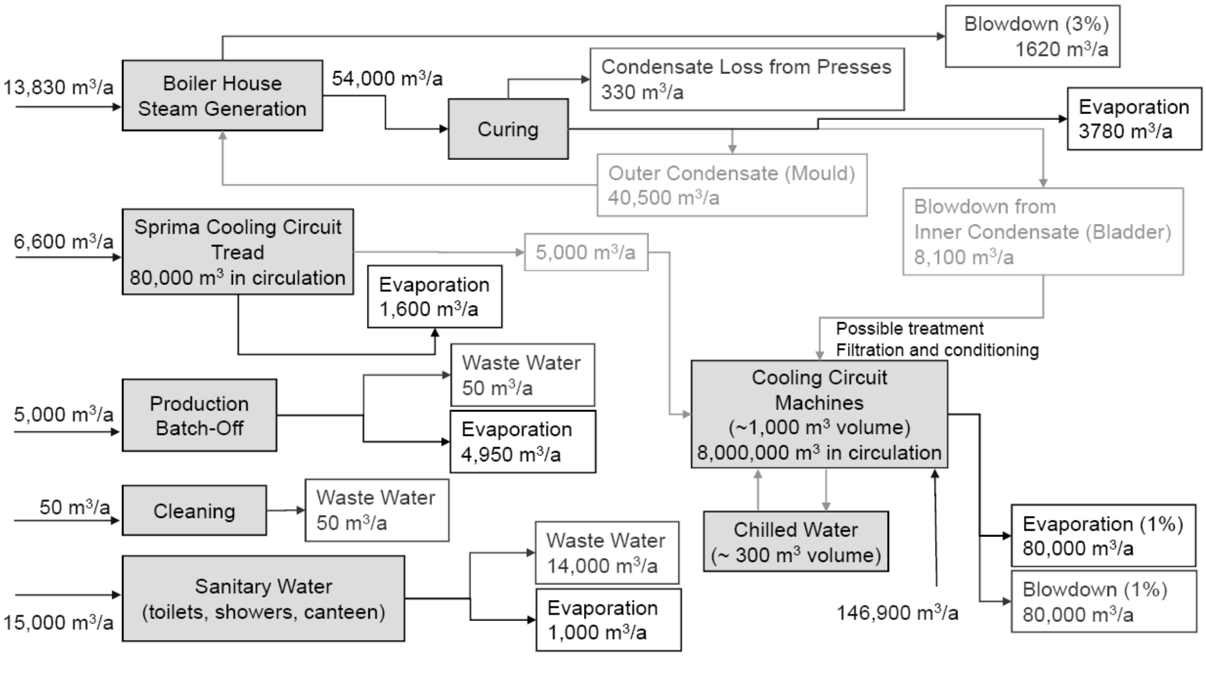


Figure 2: Water flow, courtesy of Dr. Silke Krömer, Continental AG

3.2 Water Consumption

Makeup water to replenish water losses from blowdown, filter backwash, evaporation, and winddrift represents about 78 % of the facility water demand, ca. 4.3 m³/Mg of tire. Part of the steam used in curing presses has to be rejected and makeup to replenish is ca. 7 % of the total water demand, ca. 0.4 m³/Mg of tire. Water to replace losses from contaminated tread cooling contributes ca.

4 % of the total water demand, ca. 0.2 m^3/Mg of tire. To replace water losses from batch off ca. 3 %, ca. 0.1 m^3/Mg of tire, is required. For both, potable water or better de-mineralized water quality is required. The remainder water demand of 8 % of the total, 0.4 m^3/Mg of tire, is for cleaning and sanitary purposes.

3.1 Wastewater Generation

Tire manufacture generates little amounts of industrial wastewater. 66 % of total wastewater, ca. 2.4 m^3/Mg of tire, originates from cooling tower blowdown. Circulating water is described in Guideline VDI 3803.

Table1: Abstract VDI 3803 Guideline for circulating water in cooling towers/10/

Value		c-steel	c-steel coated
pH		7.5-9.0	7.5-9.0
total salts	mg/l	<1,800	<2,100
Conductivity	µS/cm	<2,200	<2,500
harndess (Carbonates)	°dH	<4	<4
harndess with stablization	°dH	<20	<20
Cl^-	mg/l	<150	<250
Microbiologic content (no Biocid)	counts	<10,000	<10,000
Legionella	counts	<10	<10

Sanitary wastewater represents 11 % of the total wastewater generation.

Condensate from curing presses (Ca. 0.24 m^3/Mg) is reused directly in cooling tower circuits. Rejected condensate from curing presses to be discharged to wastewater system represents only ca. 0.4 % of total wastewater (0.01 m^3/Mg of tire). COD between 87 and 750 mg/l, BOD5 below 5 mg/l, extractible organic solubles 630 mg/l have been reported for different manufacture facilities. Treadline cooling systems include a series of spray nozzles, which spray cooling water directly on tread as it is carried on a conveyer belt within a cooling tank. Due to direct contact of cooling water with tread, water quality, microbial control and selection of treatment chemicals all have a significant impact on both equipment and product quality. Average microbiological counts are typically at 105 CFU/ml /12/ and stream is commonly directly feed to cooling towers.

Wastewater from floor cleaning is characterized by COD up to 23,000 mg/l, BOD_5 about 3,500 mg/l, P_{total} ca. 20 mg/l, and NH_3-N ca. 160 mg/l. Discharge from batch-off has COD up to 2,700 mg/l, BOD_5 about 470 mg/l, and suspended solids of 22,000 mg/l. Quantities range only about 1 l/Mg of tire, less 1,000 ppm of total wastewater generation.

4 Wastewater Reuse Project

4.1 Wastewater Reuse

Construction permit only allowed rainwater discharge and excluded any sanitary and industrial wastewater, even treated, from the sewer system. The permit allowed, however contradictorily, cooling tower blowdown discharge to rainwater sewer. Despite these incoherencies, the owner decided to proceed and to implement complete reuse of sanitary and industrial wastewater. Two alternatives have been studied: a) treatment of blowdown and permeate reuse as makeup, and b) demineralization and conditioning of makeup in order to operate cooling towers without blowdown. Zero liquid discharge (ZLD) design is becoming more common and less costly and more efficient than alternative air-cooled condensers./11/

4.1 Cooling Tower Blowdown Treatment and Reuse

The initial reuse process consists of three steps: Hardness and suspended solids removal, carbon dioxide removal, RO treatment at elevated pH, called (High Efficiency Reverse Osmosis) HERO^{TM}/11/ and crystallizing of reject to remove salt content from the system.

The RO system (#44) is operated at a pH as high as possible, but <11.0 in the RO reject. For pH control caustic is dosed (#45) and all hardness and other cationic species that would scale the membranes must be removed in softerer (#43). Suspended solids to be removed in prefilter (#41) and ultrafiltration (#42) should be near zero to minimize membrane plugging. Carbon dioxide is removed to the extent practical to minimize buffering. Silica is highly soluble at elevated pH and therefore does not limit the recovery of the RO unit. In theory, the percent recovery achieved by the RO, after pretreatment, is limited only by osmotic pressure of the reject. The process is expected to achieve recoveries of 90% and higher for most cooling tower blowdown applications./11/

Sanitary and industrial wastewater is treated in MBR reactor. To protect MBR membranes from fouling and scaling, individual septic tanks have been foreseen for sanitary wastewater streams. There preliminary degradation of biodegradable matter occurs (small bore sanitation). To prevent forming of ropes, hair trap has been planned.

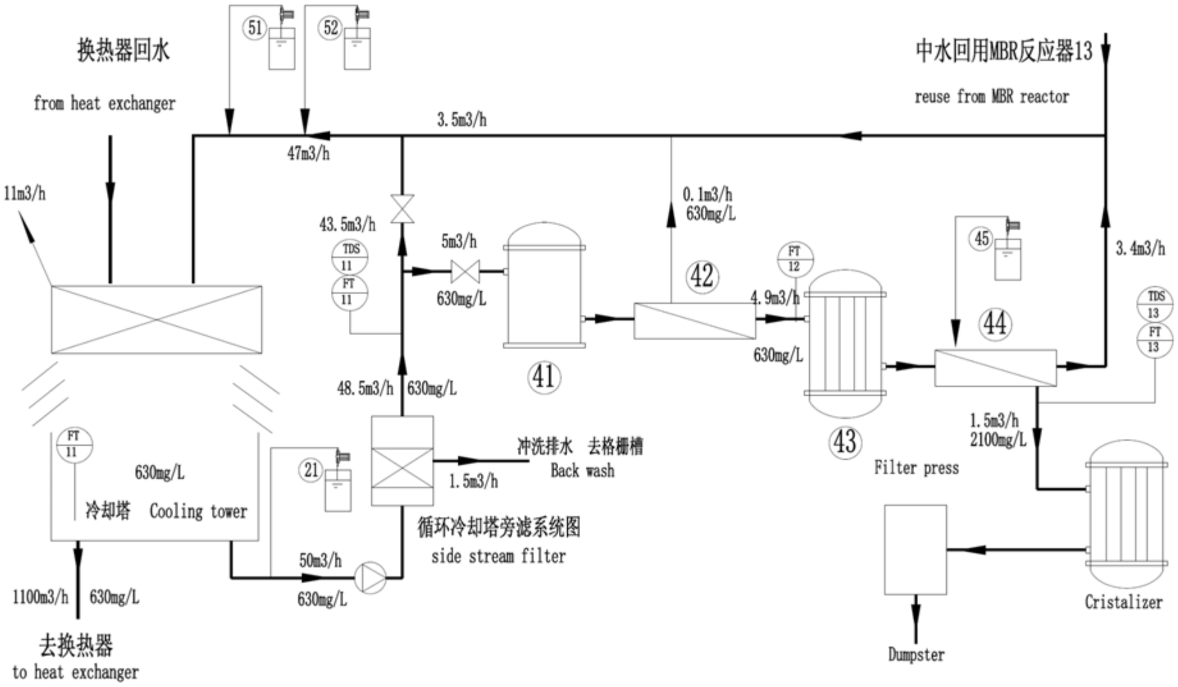


Figure 3: Blowdown HERO^{TM} treatment, courtesy of Hoahua Eng. Corp.

4.2 Cooling Tower Feed Treatment

During design, the treatment of blowdown changed to treatment of makeup water. Operating cooling towers with demineralized water, blowdown is not necessary for a couple of years, and extreme numbers of cycles are possible. A RO plant for makeup water demineralization will be applied instead of membrane filters for wastewater application.

Highly cycled soft water is much more corrosive than soft water; and the water management must provide superior corrosion control. Specific chemistry that controls corrosion of ferrous, galvanize, aluminum, and yellow metals in a highly cycled soft water environment is necessary. The corrosion control chemistry is based upon polysilicates working in combination with organic inhibitors and advanced polymers. Cooling towers using soft water makeup and specific chemical products routinely obtain steel corrosion rates well below 50 nm/yr, rates between 6 and 1.2 nm/yr are common./8/

RO reject is to be removed from the system, as above applying crystallizer. Wastewaters are to be treated in MBR and fed to makeup RO.

5 Conclusion

Complete reuse of all wastewater streams is possible, complying with Zero Liquid Discharge requirements, and reducing significantly the freshwater consumption and keeping energy absorption low. Water is finally evaporated in cooling towers, and contaminants to be removed from the system end up in solid matters.

Any zero Zero Liquid Discharge project includes clever combination of different types of membranes and water conditioning.

6 Bibliography

/1/ Continental AG: www.conti-online.com (May 2009)

/2/ Continental AG: Tyre Basics – Passenger Car Tyres, Hanover, 2008

/3/ Continental AG: "Continental Land Opening Ceremony for New Tire Plant in Hefei, China". Hanover October 10, 2008

/4/ Michelin: Factbook 2009 – The World Tire Market; www.michelin.com (May 2009)

/5/ Human Resources and Skills Development Canada: Rubber Industry; www.hrsdc.gc.ca (May 2009)

/6/ Encyclopedia Britannica: Calendering; http://www.britannica.com

/7/ GE, Handbook Of Industrial Water Treatment

/8/ Zero Blowdown Technology (ZBT) for Cooling Towers A "Green" Technology for Water Use Reduction

/9/ Timothy Keister: Cooling Water Management Basic Principles and Technology

/10/ Gohl GmbH, H. Auer: Abschlämmung durch Leitfähigkeitsmessung, TB: 21-7/03

/11/ Charles H. Fritz, Black & Veatch Corp.; V. J. Nathan, Aquatech International Corp.: HERO Process – Recovery/Reuse of Cooling Water Blowdown and as a Preconcentrator for ZLD Application

/12/ Ashland Water Technologie: Improving a Tire Manufacturer's Process and Product Quality with a Chemical-Free System