Efforts to reduce cooling water consumption in a region with limited water supply

The water treatment plant – typically referred to as an auxiliary plant – is essential for ensuring the continuity of production and plant operations in a steelmaking facility. If water resources are limited, a non-conventional approach is needed to design a water treatment plant with low water consumption. For a steel plant in a desert area cooling equipment with low water consumption and internal recycle of treated water drains has been adopted to reduce raw water consumption down to approximately only 120 m³/h on a daily average. This allowed to respect the limits imposed by the availability of water on site and to maintain a safety margin for an extension planned for the future.

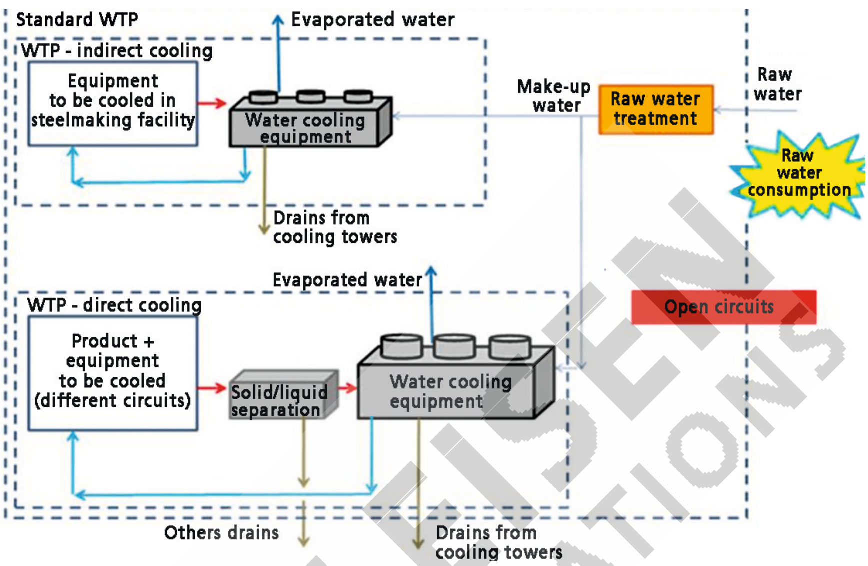

Figure 1. **Simplified process diagram of a traditional water treatment plant**

In a steel plant, the water resource is vital to the operations since water is used as cooling fluid for the equipment and the steel. Although referred to as "auxiliary equipment", the water treatment plant is essential for ensuring the continuity of production. Even though water saving has become an increasingly felt need, usually no particular attention is paid to it in the design process for production facilities. A conventional water treatment plant uses open cooling circuits, with cooling towers and the resulting evaporative water loss **(figure 1)**.

Perteco, an engineering company based in Italy, dealt with a case in which the water shortage called for a non-traditional approach. An unconventional water treatment plant was required to serve a steelmaking facility under construction in a desert area. The extreme environmental conditions and the stringent water consumption limits made the study and the implementation of this project a real engineering challenge, which has meanwhile been successfully coped with. To comply with the required limits of water consumption, it was necessary to fully review the usual approach, studying ad hoc solutions, both with regards to process and equipment selection.

Cooling requirements

For the project on hand, the demanded cooling water capacity is approximately 10,000 m³/h, for several users:

- EAF (capacity: 170 t),
- ladle furnace (capacity: 170 t),
- six-strand continuous casting machine,
- air separation plant,
- fume treatment plant,
- other users (compressed air station, SVC).

The total water capacity is divided up into several circuits. The total amount of thermal power to be removed is in the order of 200 MW. The circuit dedicated to the cooling of the fume treatment plant distinguishes itself from the others in terms of the temperatures required. In particular, the input temperature is higher than the others (55°C instead of 35°C or 40°C). The capacity and thermal power of this circuit corresponds to approximately half of the total.

Adverse factors for the design of the water treatment plant are the climatic conditions, scarcity of raw water and the margin required. The steelmaking plant was designed to produce 1,500,000 t/year of billets and is placed in a desert area, characterized by an annual temperature range between -16°C and +45°C

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and very adverse climatic conditions. The maximum wet bulb temperature is 25°C and the maximum dry bulb temperature is 45°C (design values). These temperatures define the lower unreachable limit of water cooling by evaporation (traditional solution with evaporative cooling towers) and dry coolers (coolers with closed circuits) respectively. These temperatures have to be considered for the design of cooling equipment with an adequate margin, which is typically of 5°C. So it will not be possible to reach temperatures below 30°C and 50°C, adopting the traditional evaporative cooling towers or the dry coolers as alternative solution.

The raw water available on site comes from an upstream civil waste-water treatment plant. Raw water consumption has been strictly limited to 180 m³/h (maximum value as average daily water flow). Additionally, a margin of 20% in raw water consumption has to be taken into account for future expansions planned for the steel site. So the maximum raw water consumption is below 180 m³/h.

A reverse osmosis treatment is applied to treat the raw water and produce make-up water in the quantity and quality required to compensate water losses in the plant. Also chemicals have to be added to the make-up water to improve its characteristics and to avoid scale and corrosion problems inside the circuits. With the traditional solution, raw water consumption is estimated to amount to approximately 600 m³/h (worst day case).

Genius solution to a challenging task

It is evident that the required consumption (below 180 m³/h) is much lower than that obtainable with a traditional approach, including reverse osmosis for the raw water treatment and chemicals addition to make-up water (approximately 600 m³/h). The target is to identify a configuration for the water treatment plant which:

- respects the limits imposed on the available raw water,
- ensures continuous and reliable operation,
- provides an acceptable solution in terms of investment and management costs.

The solution was found by acting on two fronts: First, appropriate equipment had to be chosen for water cooling. Second, discharges from the water treatment plant had to be recovered by way of an appropriate treatment to enable re-use within the same water treatment plant.

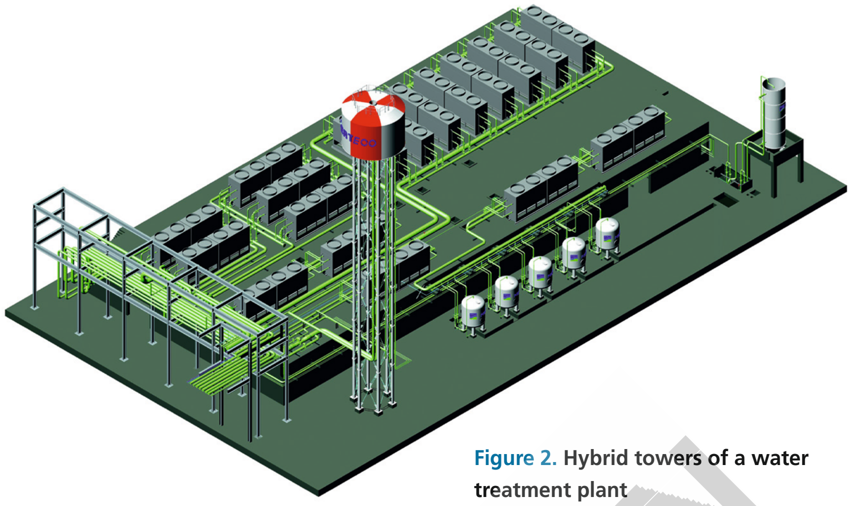

Figure 2. Hybrid towers of a water treatment plant

Appropriate equipment. Dry coolers and hybrid-cooling towers (figure 2) represent viable alternatives to reduce water cooling consumption. In fact, the dry coolers cool the water circulating in a closed coil without leakage. Cooling occurs by heat exchange through forced flow of ambient air, with the use of fans included in the cooling equipment.

The hybrid-cooling towers represent an intermediate solution between the traditional cooling towers and dry coolers and can operate in either wet or dry mode depending on climatic conditions. Even in such equipment the water intended for the cooling of the plants circulates in a closed coil. Cooling can be performed by spraying cooling water (wet) from the outside or by forced ventilation only (dry).

For the purpose of comparisons between the different equipment, it was assumed that the same thermal power has to be removed and that there were no environmental limits for closed circuits coolers that would prevent their use. Information derived from data from different suppliers has been taken into account. Figure 3 indicates the results based on data from different suppliers. It seems that the dry solution is the best option.

In reality, the type of equipment used has to take into consideration the site

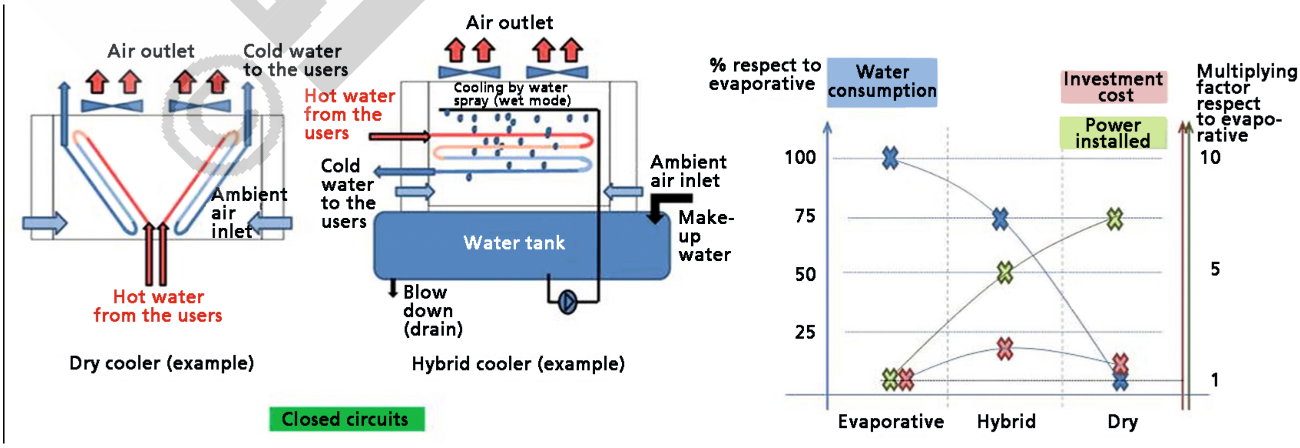

Figure 3. Closed circuit coolers and comparison with the traditional evaporative coolers

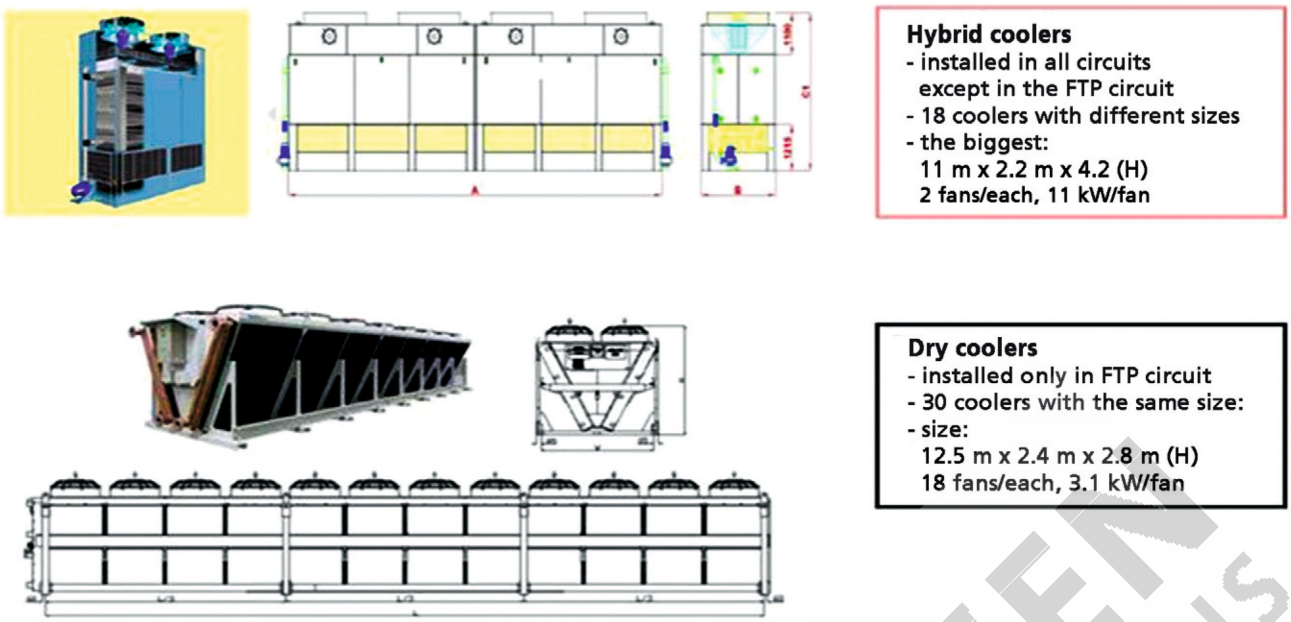

Figure 4. **Selected equipment with closed circuit for low water consumption**

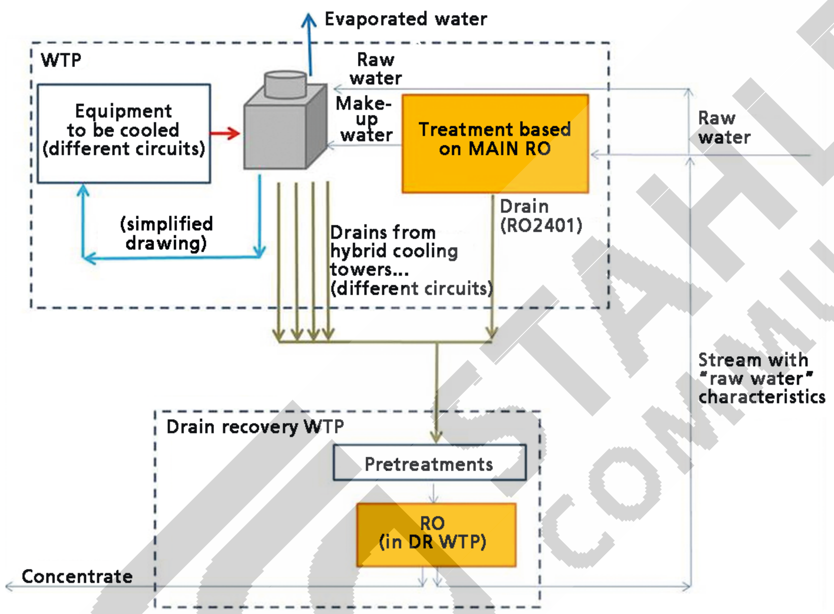

Figure 5. **DR-WTP included in a water treatment plant**

conditions. According to the climatic conditions and the required inlet temperature at the various consumption points, it was not possible to install the dry coolers in all circuits. Their application turned out to be ideal only for cooling the circuit for the fume treatment plant, due the high temperature accepted here. The equipment to be adopted was therefore selected as shown in figure 4: dry coolers for the FTP circuit and hybrid towers for all other circuits.

With the adoption of the above-mentioned equipment, the estimated consumption of raw water, also considering the osmosis process for its initial treatment, was still not within limits. In fact the estimated daily average consumption was approximately 160 m³/h and the adequate safety margin was not met.

In order to achieve additional saving of raw water, a recovery facility of the drains (drains recovery water treatment plant: DR-WTP) was adopted, using the experience gained by Perteco technicians during the provision of a similar facility serving a direct reduction plant also located in a desert territory.

Drain recovery. Figure 5 shows the simplified process diagram with reference to the circuits cooled with hybrid coolers and the adoption of a plant for the recovery of drains. The design flow rate for all drains treated by the DR-WTP is 63 m³/h, as maximum capacity. This capacity includes the drains from the various hybrid cooling towers and the concentrate discharged from the reverse osmosis that treats the raw water. Much more than 50% of the discharges can be recovered from the recovery system through adequate pre-treatment and dedicated reverse osmosis, obtaining approximately 40 m³/h as average daily water with quality similar to raw water.

This recovered flow rate corresponds to the raw water saved by adopting the DR-WTP. The DR-WTP was integrated in the water treatment plant process flow diagram, achieving a consumption of raw water of approximately 120 m³/h as a daily average. It was considered as the final solution to the challenging task (table 1).

Comparison with traditional solutions

The final comparison between the solution adopted and the traditional one is summarized in table 2, giving advantages and disadvantages. Although electrical energy consumption will increase by approximately 25%, evaluated as yearly average, resulting in additional energy costs compared to the traditional solution, it is interesting to note that both in the traditional and in the adopted solution the main part, namely more than

	Estimated raw water consumption		
	Peak value	Daily average	Remarks
Design limit	250 m³/h	180 m³/h	
Reference case: evaporative cooling towers	670 m³/h	600 m³/h	Limit not met
Hybrid and dry coolers	180 m³/h	160 m³/h	Limit met, but without reserve
Hybrid and dry coolers PLUS drain recovery WTP	130 m³/h	120 m³/h	Adequate solution

Table 1. Water consumption of a traditional solution (reference case) in comparison to the developed solution

	Reference case	Hybrid and dry cooler + DR-WTP	Effect	
Raw water consumption (average)	600 m³/h	120 m³/h	- 80%	Advantage
Make-up water feed (average)	430 m³/h	160 m³/h	- 65%	Advantage
WTP footprint	4,050 m²	9,300 m²	+ 130%	Disadvantage
Volume of concrete tanks	6,885 m³	4,590 m³	- 35%	Advantage
Electrical power installed	6,280 kW	7,999 kW	+ 25%	Disadvantage
Consumption of chemicals	12.5 kg/h	5 kg/h	- 60%	Advantage

Table 2. Comparison between adopted solution and traditional solution (advantages and disadvantages)

60%, of the installed electrical power in a water treatment plant is accounted for by the installed water pumps.

However, the adopted solution provides considerable savings of water and associated chemicals with an important impact on operating costs. Considering an estimated cost of 0.40 – 0.65 US$/m³ for chemicals to be added to the treated water, 8,000 h/year of operation and savings amounting to 270 m³/h (430 m³/h – 160 m³/h) of make-up water (allowed by the solution adopted), it is estimated that the savings on the cost of chemicals may reach values in the order of 1.4 million US$/year.

Conclusion

The solution adopted differs from traditional approaches due to the following aspects:

- use of equipment with low or negligible water consumption (hybrid-cooling towers and dry coolers),
- study and application of a plant for the treatment and recovery of the drains (drain recovery water treatment plant – WTP).

With this solution in place, it will be possible to obtain a raw water consumption of only approximately 120 m³/h as daily average, while respecting the limits imposed by the availability of water on site and maintaining a safety margin for the planned expansion of the steelmaking facilities.

In respect of the higher investment cost needed to adopt the solution identified, the savings of water and chemicals are particularly advantageous in economic terms. For this case, it is estimated that these savings will outweigh the higher costs of investment in less than five years, making the validity of the solution adopted sustainable and convincing. The efforts adopted to satisfy the requirement of low water consumption at the described site have made it possible to highlight a non-traditional approach that could be applied and provide an economically viable solution for other plants of the steelmaking route, like direct reduction plants, hot rolling mills or other industrial facilities.

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