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# Water Conservation through the Utilization of Advanced Performance Die Lubricants

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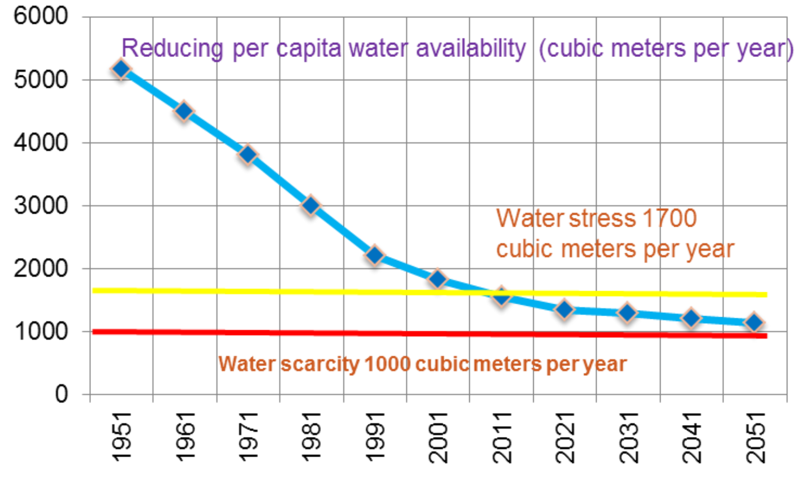
## Abstract:

Current year (2016) has seen normal monsoon but this comes after two consecutive years of below-normal monsoons. India faced severe drought-like conditions in 2015. This situation was worsened due to the acute heat wave that has affected many parts of the country. A year of good monsoon is not enough to replenish the depleting water bodies. Lakes, ponds and rivers are drying up, leaving villages and cities with depleted sources of ground water. This forces many die casters to transport water into their facilities, at extra cost, from numerous sources including rivers, ground water and lakes to dilute die lubricants. The varying quality of this water will have a major impact on the die casting process. Moreover, many die casters exacerbate issues by over-diluting their die lubricant as a falsely perceived cost-saving measure. This actually leads to lower productivity and higher cost while also wasting the valuable water resource so needed throughout India. This paper discusses how the proper utilization of die lubricant has the power to increase productivity and profitability for die casters, while also conserving the scarce water resource.

## Water Crisis India:

The water crisis in India is exceeding critical levels. According to data from the Indian Ministry of Water Resources, the country surpassed the per capita water stress level of 1,700 cubic meters per year in 2011 and is quickly approaching the scarcity level of 1,000 cubic meters per year level in the coming decades (Figure 1). After two successive dry years in 2014 & 2015, 330 million inhabitants (around a quarter of India's population) faced acute water shortages.[1] On top of this, India's Central Ground Water Board has reported that over 40 percent of the 660 districts have high levels of fluoride and well over 15 percent have high nitrate levels. Furthermore, 86 districts tested positive for arsenic[2]. Taking all of this into consideration, the argument can easily be made that this is far beyond "crisis" levels. The question then is posed: what can the Indian die cast industry do to help with sustainability efforts in light of this crisis?



*Source: Ministry of water resources (Govt of India)*

*Figure 1*

The die casting process consumes a significant amount of water with the application of die lubricant. This can be eliminated through optimized internal cooling and utilization of Chem-Trend's HERA™ MicroSpray technology; however, this is not practical for most die cast operations and is also the subject of a separate paper. With this said, most die casters can greatly reduce the amount of water-diluted die lubricant needed through proper technology selection and utilization of modern formulations.

It has become common practice in many emerging markets to extend die lubricant dilutions to nearly 1:300 and well above. This is due to the widespread misconception that additional dilution of die lubricant will lead to cost savings. In reality, this actually results in higher costs and lower productivity through extended cycle times and higher downtime and scrap rates – along with excessive water and electricity consumption (waste).

**<u>Die Lubricant Functionality</u>:**

Die lubricants have a significant impact on the die cast process. Although the primary function is to release the part while providing an effective barrier coating on the tooling steel for solder protection, they also have a major impact on part surface quality and metal flow. However, they are often heavily relied upon to manage thermal balance of a die. This management of thermal balance is where proper die lubricant selection and application (including dilution practices) has a major impact on the process.
The scientific aspect of die thermal management through the use of die spray is summarized in a heat flux curve (Figure 2). [3,4] The X-axis of the graph (read right to left) depicts temperature. During the initial spray time, heat flux is very small as surface wetting has not taken place. During this so-called "film boiling regime," a gas barrier forms on the surface if the surface temperature is high enough. This vapor film has a high vapor pressure, and therefore resides close to the hot surface. The vapor prevents the physical contact of the water droplets with the heated surface (Figure 3). This vapor barrier effectively insulates the surface, resulting in a low rate of heat extraction from the hot surface.

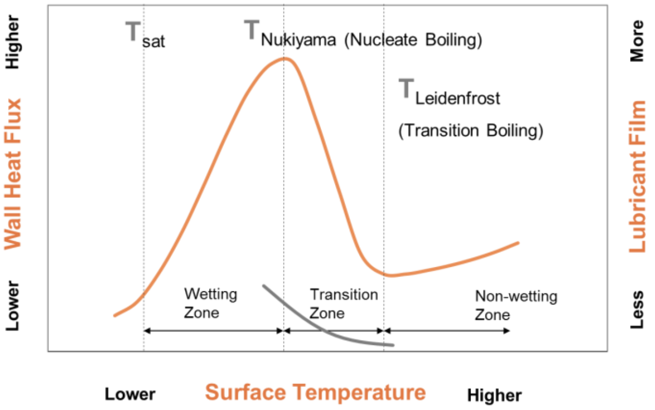
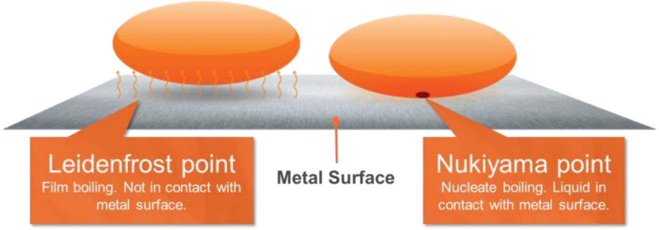


***Figure 2: Change of heat flux with temperature in forced convection cooling due to spray impingement.***



If liquid does not contact the surface, lubricant film cannot be formed.

***Figure 3: Leidenfrost phenomenon restricting lubricant from contacting die surface.***

This regime continues until the Leidenfrost point[5]. Once the temperature has fallen enough for surface wetting to take place, the cooling curve moves into the transition regime, and rate of heat extraction from the die starts to increase, reaching a maxima. At the Nukiyama point the heat transfer coefficient and heat flux maximize; this maximum heat flux is referred to as critical heat flux (CHF). At this point, the heat transfer curve transitions into the nucleate boiling regime, followed by the boiling regime, and the rate of heat extraction gradually decreases through both these regimes[6]. Further cooling leads to the saturation temperature or boiling point. In addition to heat transfer, die lubricant film formation also starts at Leidenfrost temperature and continues on through the transition and nucleate boiling regimes; film formation is most efficient in these regions.

Now that the science of die cooling is outlined, let's examine some actual cooling data. Chart 1 shows a graphical representation of a cooling curve for actual die lubricants compared to water. This is a laboratory test that shows comparative data between the materials. It is not useful to interpret the data alone as stating that Lube "A" will cool the die 225°C within 15 seconds as there are many other factors; however, the relative performance detailed herein can be instructive.

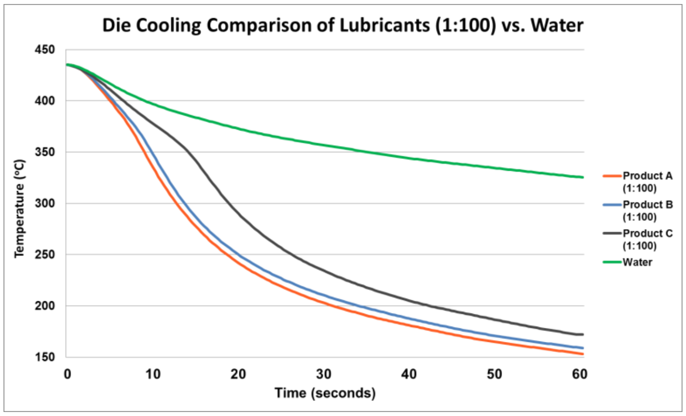


***Chart 1: Die Lube Cooling Profile vs Water***

Die lubricants extract heat from a tooling surface far quicker than water for a more efficient process through shorter spray time. Furthermore, it is obvious that all die lubricants do not provide identical heat extraction properties due to their varying ability to break through the Leidenfrost point. Yet, all are more efficient than water, which did not even break through the Leidenfrost point under these test conditions. In practice, it is common to reduce spray time by 30-50 percent based upon technology selection. The corresponding thermal imagery seen in Figure 4 shows on die cooling performance of two die lubricants applied under the same exact spray settings.  In this case, the caster was able to cut significant spray time out of their cycle for greater productivity which has a direct correlation with profitability.  Due to the improved lubricant chemistry, the process could also operate at a higher temperature while actually improving solder performance and overall part quality.  These improvements in lubricant on-die performance also has a direct impact on a die casters profits through less downtime for desoldering of the die and the subsequent reduction in start-up shots (scrap), improved die life due to less polishing and all of the positive attributes resulting from improved part quality.

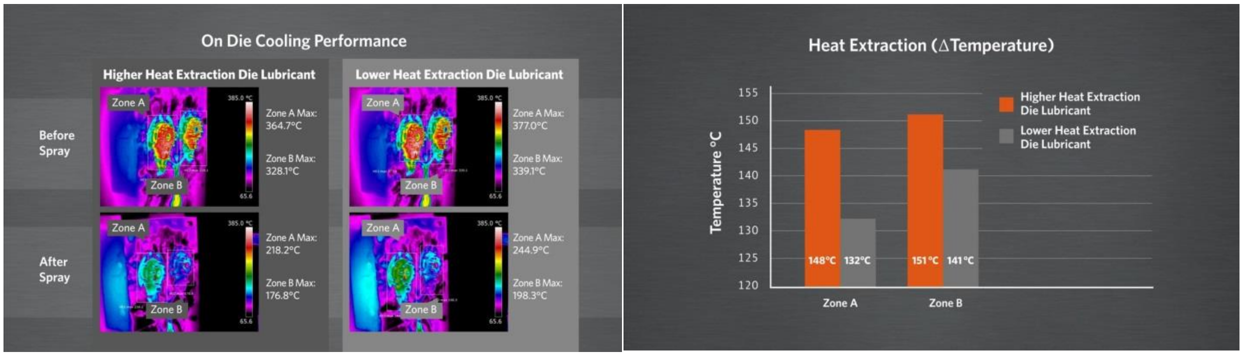


***Figure 4 (A&B): On Die Cooling Performance - Varying Heat Extraction Die Lubricant Formulas***

***Note:*** *Figure 4 highlights that the high heat extraction die lubricant will remove 148C and 151C from Zone A&B respectively.  Meanwhile, the lower heat extraction die lubricant will only remove 132C and 141C from the same zones while applied under the same exact settings.*

**Performance vs Dilution:**

The cooling data above shows that die lubricant is more effective than water – but, some may ask, what's the harm in diluting a little further to save cost?    Chart 2 identifies the impact dilution has on two different die lubricant technologies.  In essence, the performance gained with more efficient technology is lost through excessive dilution.  This concept is also supported by Charts 3 and 4 that identify varying wetting time and temperature characteristics.  Dilution of 1:100, 1:300 and 1:500 were used for the majority of this presentation; however, Charts 3 and 4 use a dilution of 1:200 to illustrate the sudden and significant drop in performance caused by excessive dilution.

This is why sophisticated die casters globally have shifted away from excessive (1:300 and even 1:600) dilution levels to a more reasonable 1:75 to 1:125 range.  Resisting the temptation to "dilute a little extra" optimizes the die cast process by utilizing as little spray time and lube volume as possible.  It is interesting to note that water conservation is not necessarily a focus in every region, but reducing and eliminating the resulting waste water treatment and disposal is a universally acknowledged benefit.

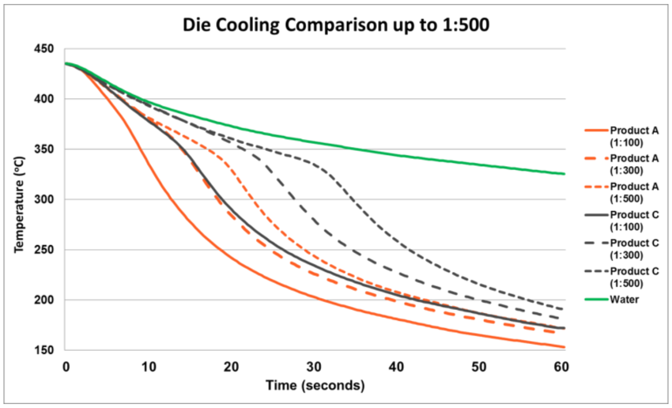
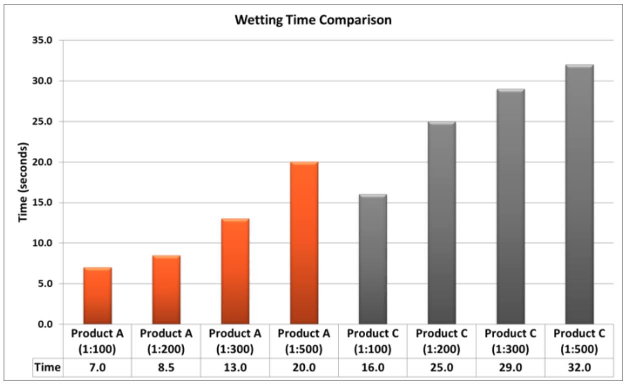


*Chart 2: Die Lubricant Cooling Performance vs Dilution*



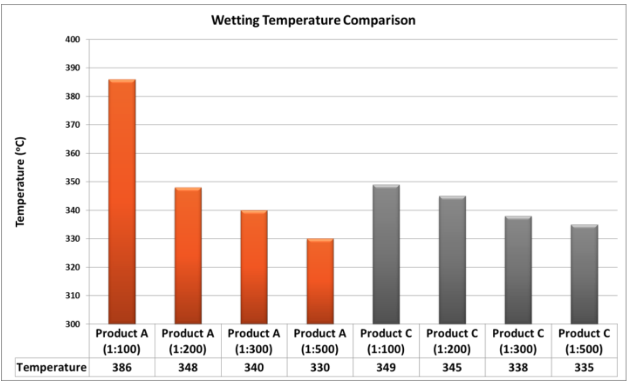


*Chart 3: Wetting Time (faster is better)* *Chart 4: Wetting Temperature (higher wets quicker)*

**Film Functionality:** Along with the time and productivity impact on a process, over-dilution of die lubricant also affects the functionality of the die lubricant film. As noted in the heat flux curve, the protective die lubricant barrier is formed on tooling surfaces only after the Leidenfrost temperature is met as the cycle shifts toward the Nukiyama point. Excessive dilution reduces this wetting temperature, resulting in a slower and less efficient film build. This becomes most visible in a laboratory setting through analyzing die lubricant wetting and spreading diameter per Figure 5 and Chart 5. On the other hand, what cannot be shown in these laboratory tests is the functionality of the film. Release films developed at these higher dilutions do not provide the same metal flow and solder prevention characteristics. This leads to lower quality castings due to drag marks, porosity and other flow-related defects. Moreover, this leads to additional downtime to polish the die surface while also having a negative impact on die life. A final often overlooked attribute is corrosion protection. Die lubricants also contain corrosion inhibitors to protect the mold and die cast machine componentry which become ineffective when highly diluted.

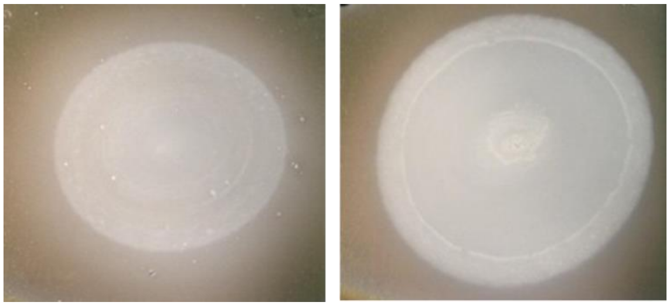


*Figure 5: Wetting Diameter*

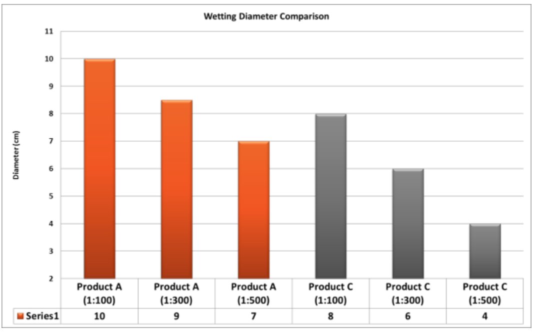


*Chart 5: Wetting Diameter (measured)*

**Water Quality:**

Water quality itself will negatively impact die lubricant performance due to biological activity and dissolved water solids. Increased biological activity is often present when casters must transport and store water during drought conditions. This biological contamination is often the root of many die lubricant system challenges because the emulsifiers that hold a lubricant together are actually an excellent food source for bacteria. Once a system is contaminated, biological activity grows exponentially and attacks the die lubricant. This leads to split lubricant with low performance and system plugging issues. Some chemistries are more bio-stable, such as Chem-Trend's BIT™ Technology (Bio Inhibiting Technology), but all are susceptible to biological attack. Again, high dilutions exacerbate this impact as the emulsion is weakened and die lubricant performance is lessened, resulting in decreased productivity and profitability.

Hard water also leads to many quality issues. It is recommended for casters to use soft water with a maximum dissolved solids level of 150 ppm. Here the old adage of "an ounce of prevention is worth a pound of cure" comes to mind. Within each cycle, whatever contaminants are dissolved in the water will remain behind on the die when the water itself boils off. By reducing these contaminants up front, many problems downstream will be reduced or eliminated. The most immediate impact of hard water is overspray buildup in the flange area of the die and carbon buildup in the die cavity. Both are often mistaken as die lube issues when dissolved water solids deposit along with the lubricant film. This is easy to verify through a simple chemical analysis of the buildup for hard water mineral levels.

As an example, suppose a die caster is attempting to use water with 300 ppm of dissolved solids. Chart 6 identifies the ratio between deposited die lubricant and deposited hard water solids at varying dilution lengths. At a 1:300 dilution and 300 ppm water, 33 percent of the deposited solids are actually water solids!

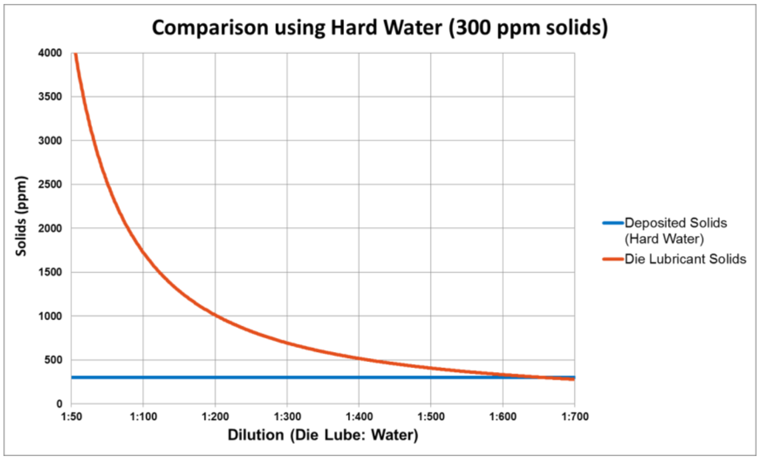


***Chart 6: Deposition Ratio***
***Die Lubricant and Hard Water Solids at Varying Dilutions***

## Summary:

Multiple years of drought due to lower-than-average monsoon rains has had a crippling effect on the people of India while also damaging the economy. There is little expectation for this to improve in light of population and industrial expansion that will only drain even more of this precious resource. Along with this, the global business environment continually challenges the die cast industry to improve productivity and meet profitability targets under a strict, globally competitive landscape.

Chem-Trend partners with industry to help die casters respond to these challenges and meet production goals. Our representatives will regularly collect water supply samples from customers to analyze and monitor the harmful effects water contamination can have on die lubricant performance through slower cycle times, additional DCM downtime and lower part quality. Furthermore, when proper technology selection runs at optimized dilution levels, a caster can actively engage this water conservation issue while simultaneously improving their process to maximize productivity and profitability.

## REFERENCES

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## ABOUT THE AUTHOER

John Belyk is the global business development director for the die cast industry at Chem-Trend. He has been with Chem-Trend for 27 years and has garnered a depth and breadth of process chemical specialty expertise that spans multiple industries and applications.

John holds a bachelor's degree in business administration and started in Chem-Trend's operations group in 1989. He then moved into technical service for the company's polyurethane, rubber, composites and tire business. He went on to become a sales representative for Chem-Trend's plastics and rubber division within the South Central region of the U.S.

In 2000, John moved into Chem-Trend's die cast division as the company's sales representative to the Canadian market segment. John embarked on his first management role for the organization in 2005 as field sales manager for the tire industry, with a position as sale manager for polyurethane following soon thereafter.

John rejoined Chem-Trend's die cast team in 2011, stepping into his current role as die cast business development director. As such, John provides strategic direction for the company's global die cast product line through leadership of Chem-Trend's technical team and marketing activities.