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Turning Tower Lights Off

FAA manager discusses the history and future of obstruction lighting.

By Edward Lundquist

Jim Patterson, manager of the FAA's airport safety R&D section at the William J Hughes Technical Center in Atlantic City, New Jersey, talks about obstruction lighting control for wind turbines.

FAA Manager Jim Patterson says obstruction lighting control has some good benefits for the wind industry.

Lundquist: *There are some people who object to the wind-turbine aircraft warning lights at night. There is technology that allows the lights to remain off unless an aircraft approaches. What can you tell me about the status of the FAA approving solutions for aircraft warning-light controls for wind farms?*

Patterson: Back several years ago, the FAA was first approached by a Norwegian company called OCAS, which stood for Obstruction and Collision Avoidance System. They had a relationship with the FAA regarding some lighting at power-line crossings probably going back 10 years ago or so. So we were familiar with this company, OCAS. The company was very involved at the local level in a lot of these wind-rich states where they knew that wind-turbine vendors would be hunting for property on which they could build their turbines. And what ultimately happened is the company was able to convince a lot of these local municipalities to write into their siting criteria that anybody who wants to build a wind turbine within their jurisdiction must use an OCAS-type system. And that caused a lot of problems at that point because OCAS had not yet demonstrated to the FAA that its technology was even worthy of performing the task. A lot of local municipalities made these agreements, put it into their local laws, and then once they did, they found out the FAA had not even looked at any of these vendors, and there were no vendors to select from. And so a lot of people have been waiting anxiously for us to finish our research, so they know who the approved vendors are. The FAA is not making these mandatory. They're not an FAA system. We simply provided, through our research, a set of performance standards, so if a wind-turbine developer were to incorporate one of these technologies into their obstruction-lighting plan, then we would want it to perform in a manner such that we have stated in our advisory Circular 70/7460-1L.

Lundquist: *Vermont's Renewable Energy Bill (S.260/Act 174) of June 9, 2016, states: "Where required by the Federal Aviation Administration, wind-energy facilities with four or more turbines must have radar-controlled obstruction lights."*

Patterson: Since I'm in Atlantic City and kind of a betting man, I would bet that OCAS probably had something to do with that back a couple years ago. I just want to make it clear that the FAA in no way is making this mandated or a requirement. We have the rules, and if you're going do it, this is how you do it. And depending on the wind turbine's proximity to any low-altitude flying route or airport, we may have to disapprove

A Terma SCANTER 5000 radar installed at Denmark's national test center for large wind turbines in Oesterild in the Northern part of Denmark. Terma's radar solution obtained final approval from the Danish authorities for a five-year operational test period. Terma's obstruction lighting control radar is one of two approved by the FAA. (Courtesy: Terma)

obstruction lighting control just based on the obstruction's location. So it's important to know that not all applications will be approved — it is very site-specific.

Lundquist: *Which systems are approved?*

Patterson: We did conduct an evaluation of OCAS' system at a wind-turbine farm up in Talbot, Ontario. We went up there to evaluate one of OCAS' systems they installed. And we conducted our evaluation using a helicopter, and we found the detection distance wasn't quite what we were looking for. It was only able, at that time, to detect us about

ALSO IN THIS SECTION

a mile and a half out. We felt that at a reasonable speed you could expect from a small general-aviation aircraft traveling that close to the ground, that it wasn't enough time for a pilot to acquire the lights, recognize what he or she is looking at, and take the evasive action to avoid the obstruction. So we started doing work to back that up and found three miles is the requirement we have for forward visibility for visual flight rules. That ties to everything the FAA has ever looked at historically — the pilot needs about three miles to acquire something, understand, process what it is, and then move the aircraft to avoid it. With that three-mile distance in mind, we worked with a company called Laufer Wind Group out of New York City, and we were able to facilitate an evaluation of their technology with the Department of Energy at the National Renewable Energy Lab, or NREL, in Boulder, Colorado. Laufer was able to install its sensors on some prototype wind turbines out in Boulder, and we used an aircraft to fly and validate the system to prove it met the standards we had put down. We published that report on our website. We also started working with a company called Terma on their obstruction lighting control, or OLC. The company has heavy ties to military, and its technology is quite proven for port and harbor protection in its ability to find small vessels, ships, and any type of movement that might be on a body of water. It's a long-range sensor, and a little bit bigger than the Laufer system as far as the sensor requirements. But all-in-all, we were able to facilitate a demonstration of that out in Mojave, California. That solution has been approved, and that report is now published and available on our website as well. So, as of right now, we've got two technologies out there: the Laufer system and the Terma system. Those research reports are finished and available on our website.

Lundquist: *There's another company, DeTect, which claims to be approved.*

Patterson: They are not yet approved, so to speak. We have been working closely with them, and we actually conducted our evaluation right in northern New Jersey, up in Andover. We actually just completed

Green Mountain Power (GMP), a utility serving 265,000 customers in Vermont, wanted to install obstruction lighting control radar when its 21 turbines at Lowell Mountain began generating power five years ago. The turbines have eight aircraft warning lights to meet FAA requirements. (Courtesy: Edward Lundquist) our flight test on a power-line crossing with them just a few months ago, and that report is still being worked on. So once we're done with that, their report will be out, and they would be the third approved vendor.

Lundquist: *Any others?*

Patterson: OCAS ended up being acquired by Vestas North America — one of the largest wind-turbine companies out there. They have a new team of engineers that has totally overhauled the system and has corrected all of the issues. So we were able to successfully negotiate with them to try to come up with a test site and were invited over to Braderup, Germany, to conduct our performance assessment. We were successful with our effort in Germany, and as of right now, we are working with the vendor to facilitate an installation here in the U.S. so we can verify the system meets our domestic frequency requirements. We're trying to be accommodating. We already have completed the report with data and information from the assessment in Germany and will plug in the remaining information when it becomes available. Once done, Vestas will be the fourth approved vendor.

So as of right now — I hate to use this term — we only have four vendors on our radar.

Lundquist: *Thank you. Any last thoughts?*

Patterson: Obstruction lighting control has some good benefits. It prevents birds from being attracted to our FAA obstruction lighting, so it's got a very positive impact on wildlife. And it helps the nearby communities to be more acceptable to renewable energy. And we've proven that it still has the range we need to keep aircraft safe and let pilots still see the same lighting configuration they would see with or without the technology. It could be considered a more expensive "switch" to turn the aircraft warning lights on and off, and that's true, but it seems to be a solution that's really helping all parties involved.

FAA research papers are available at www.airporttech.tc.faa.gov/Download/Airport-Safety-Papers-Publications

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Aluminum Vs. Copper Conductors

How to reduce cost through the electrical cable supply chain.

Aluminum wires can be up to 60 percent lighter than comparable current-carrying copper wires. (Courtesy: Helukabel)

By Bruce McDonald

Each year at the AWEA WINDPOWER expo, there seems to be a buzz within each sector of the wind industry's supply chain.

This year was no different. Within the wire-and-cable industry, everyone is talking about continued cost reductions in the supply chain. Two cost areas in particular are the overall cost of the supply chain itself and the other is the use of aluminum conductors.

Let's address the supply chain partner reduction concept first:

For this article, the supply of cable accessories such as plastic/metal glands and fittings as being associated with the cable manufacturer will be included. In general terms, a turbine manufacturer has, on average, four to six approved cable/accessory suppliers.

Each supplier has its own account management costs within the turbine company, and exact costs vary between turbine manufacturers. Let's assume each purchase order issued to a supplier has a total internal processing cost of $60. If a company processes 30 purchase orders per month at an average cost of $60 for all six suppliers, the turbine company has $10,800 per month in just purchase order processing costs (6 suppliers x 30 POs = 180 POs x $60/PO).

If strategic supply chain partnerships are formed with a cable manufacturer that not only has a history of supplying quality cable but can also supply accessories, terminated assemblies, and kitted items, a reduction in operating costs is not unrealistic. How much of a supply chain cost savings the turbine manufacturer will see on its bottom line depends on how many individual procurement functions can be eliminated by reducing the number of supply chain partners.

The second area overheard during discussions this year was replacing copper with aluminum conductors in the cabling in the down-tower segment of the turbine.

From a cost perspective, aluminum historically has been significantly cheaper than the standard copper conductor used for wind cables. Copper is approximately two times more expensive than aluminum. The greater availability of raw aluminum compared to copper accounts for this significant difference in price. After oxygen and silicon, aluminum is the third most common element in the Earth's upper crust, while copper is ranked 25th in availability on the list of raw materials. Assessment of current prices is further reinforced by the volatility of the raw materials market.

Looking at the numbers from only the last 18 months, copper prices fluctuated within a range from $2.28 to $3.08 a pound. The price of aluminum does not fluctuate as volatilely as copper, which allows purchasing departments to make better estimates during the material-planning phase.

From a mechanical and handling perspective, the introduction of flexible aluminum stranding has displaced the notion that aluminum cabling is stiff, hard to handle, and hard to install. Switching to aluminum successfully is a matter of understanding the capabilities of this conductive metal and how to deal with the challenges it presents.

PHYSICAL AND ELECTRICAL PROPERTIES

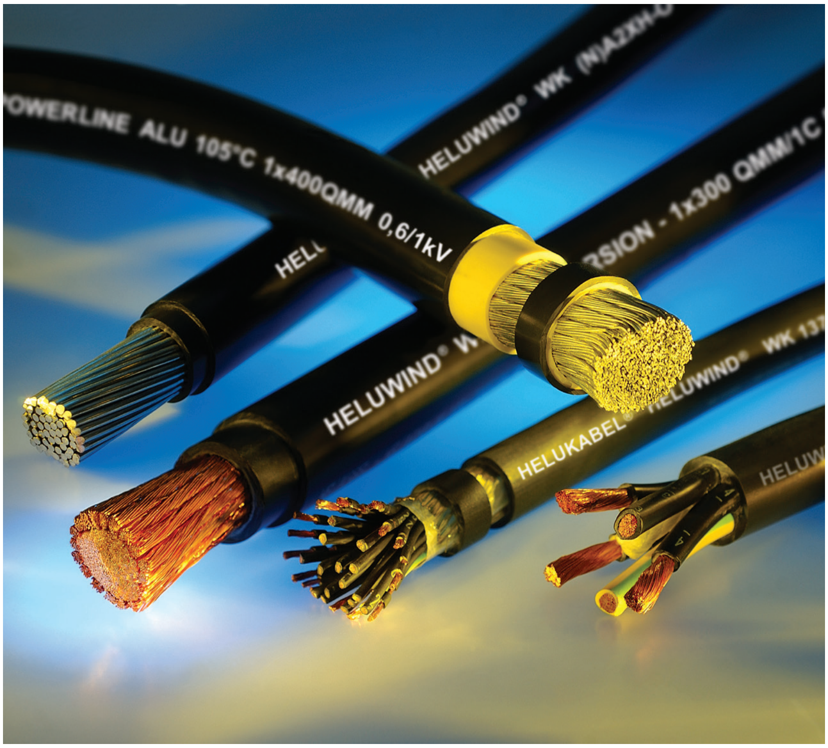
If aluminum is used as a conductor material, its lower conductivity requires a wire size approximately one-third larger than that of a copper wire with the same desired conductivity requirements. In the end, however, the insulating material used with the wire plays a crucial role in performance, and an aluminum wire can possess the same current-carrying capacity as a H07RN-F copper wire. Aluminum's larger wire size would only be a disadvantage in applications requiring tight spacing, such as in densely packed control boxes.

The facts for aluminum speak for themselves when it comes to the issue of weight. As a raw material, aluminum is approximately 70 percent lighter compared to the same amount of copper. This can be helpful in the efforts of numerous application fields looking to reduce the weight of all components. Naturally, when used in electrical cables, the lower weight makes them easier to install in less time. High-voltage lines have long been made from aluminum; the lighter weight reduces the tensile force placed on the wire and masts significantly. But even industries such as automotive manufacturing and the aeronautical industry are switching to aluminum wires. This is why entire wiring harnesses made of aluminum already are installed in the Airbus A380. Aluminum wires can be up to 60 percent lighter than comparable current-carrying copper wires.

OXIDATION IN THE AIR

When exposed to oxygen, a hard and resistant oxide coating forms within a short period of time on the surface of aluminum. The coating protects the subjacent material from further corrosion. This effect makes aluminum a highly durable material. However, the protective oxide coating on the material surface is not desirable when it comes to electrical engineering. It degrades the conductivity of the aluminum and makes contacting difficult. If an oxidized conductor is connected without any pre-treatment (to remove the coating), the contact resistance will increase between the aluminum conductor and the connector component. This can result in temperature increases and, under worst-case conditions, cable fires.

To prevent such problems, the oxide coating must be broken or removed physically. This is done by brushing the bare aluminum conductor ends before contacts are made and also during any termination process. Connector components for aluminum conductors are equipped with a special contact grease from the factory, usually a grainy, abrasive material such as corundum. Combined with high pressure, the corundum particles cause an abrasive effect that breaks the non-conductive oxide coating on the aluminum, improving contact properties and electrical connections. The grease also prevents



Aluminum cables can be a successful alternative to copper cables. (Courtesy: Helukabel)

moisture and oxygen from entering and causing any new corrosion of the contact points. Better quality cable lugs are generally equipped with plastic plugs, which prevent the contact grease from drying out or leaking during storage.

ELECTROCHEMICALPRECIOUS METALS

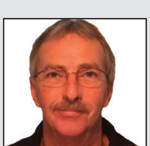
When it comes to specifying electrical connection components, the corrosive reactions of aluminum in the presence of other metals — mainly copper — also must be considered.

When aluminum comes into contact with more noble metals (metals with higher electro-potential) such as copper, iron, or brass, an electrochemical reaction may occur by means of contact element formation. This reaction is activated by conductive liquids. This manifests in the field mostly as condensed water (condensation). In this process, the potential differences produced by the electrochemical voltage series play a crucial role. The copper electrode (anode), electrolyte (water), and the aluminum electrode (cathode) create a contact element. Any voltage across these elements is short-circuited by the contact between the copper and aluminum. The resulting current creates a decomposition process in the aluminum, which is visible as a radiant oxidation point revealing the contamination of tiny copper particles. However, the copper does not decompose. But the decomposition process negatively affects the electrical connection over the long term, with increasing contact resistances that lead to temperature increases and even to fires.

Therefore, using an aluminum/copper (Al/Cu) cable lug is recommended for connecting aluminum to copper peripherals. Bimetal connectors such as Al/Cu cable lugs, press connectors, and connecting bolt pins are manufactured using a friction-welding process. They are encapsulated to prevent liquids from penetrating the connection and causing any unwanted creepage. The use of Al/Cu connectors and connections is the most sensible way of combating the effects of oxidation on aluminum.

Another means of protecting against moisture is installing a secondary insulation on the contact area. Depending on the field of application, mechanical load, and environmental conditions, a cold-roll or a heat-shrink tube can be used. The best protection results are achieved by heat-shrink tubes with an inside adhesive. At the same time, the electrical contacts should be inspected thoroughly during regularly scheduled maintenance.

In summary, aluminum cables can be a successful alternative to copper cables — in terms of performance and pricing — when the proper engineering techniques are used at both the manufacturing and end-user levels of the supply chain.



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Analysis of Aged Wind Turbines for Continued Operation

Many factors are considered in assessing aged wind turbines for continued operation through and beyond their design lives.

By Joseph F. Rakow and Torstens Skujins

As the global population of wind turbines continues to increase, large portions of the population are aging and ultimately approaching the end of their design lives. By 2020, approximately 65 percent of the U.S. fleet, comprising 30,000 turbines, will have been in operation for more than 10 years.[1] Similar situations exist in other countries that have large turbine populations, such as Germany, where nearly a third of the wind turbines have been in service for more than 15 years.[2]

As the global wind turbine population ages, many turbines have demonstrated the ability to continue operating beyond their design lives, which is typically 20 years. (Courtesy: Exponent)

Although the population ages, many turbines have demonstrated the ability to continue operating beyond their design lives, which are typically 20 years. According to the Wind Power Database, approximately 10,000 turbines in the global population of 200,000 turbines tracked by the database are 20 years old or older and remain in service today.[3]

Stakeholders in aged turbines are faced with many business decisions as they continue to seek to maximize the output of their assets in future years. Should the aged turbines remain in service? Should they be replaced with newer, higher-power and more-efficient technology? Can the turbines provide service beyond their design lives? The laundry list of factors affecting these decisions includes finance, maintenance, contracts, regulations, risk tolerance, and market conditions. One primary factor affecting these decisions is, of course, the physical condition of the turbine being considered for continued operation. Depending on the needs of the stakeholder, the physical condition of the turbine can be evaluated through a combination of physical inspections and/or analysis, the latter of which is the focus of this article.

DESIGN VS. ACTUAL CONDITIONS

One commonly accepted approach for analytically evaluating the physical condition of a wind turbine — and other types of machines across other industries — is to compare the historical environmental operating conditions of the machine to the conditions assumed during the design of the machine. For wind turbines, the environmental operating conditions include wind-speed distributions, turbulence intensity, solar radiation, temperature, humidity, and airborne salt concentrations, among others. Continued operation of a turbine is favorable from this analytical perspective when the historical conditions are more benign than the design conditions, resulting in additional operating margin beyond design.

Several sources can be consulted to identify design conditions. In certain situations, design conditions and design calculations may be available from the OEM. Alternatively and more commonly, minimum or nominal design conditions can be acquired from the standards to which the turbine is certified, such as the GL Guidelines for the Certification of Wind Turbines for GL-certified turbines. These

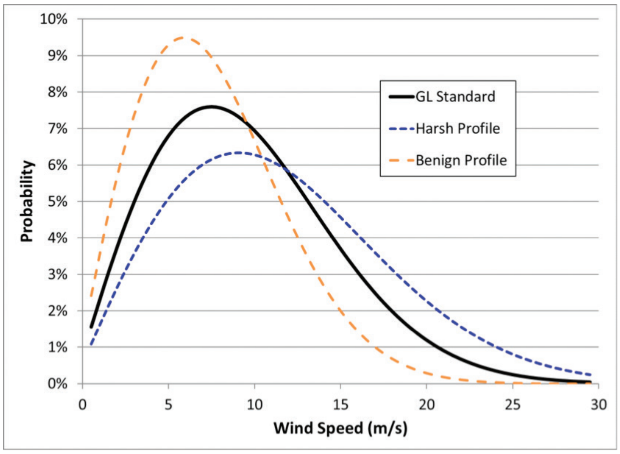

Figure 1: Wind speed probability distribution examples

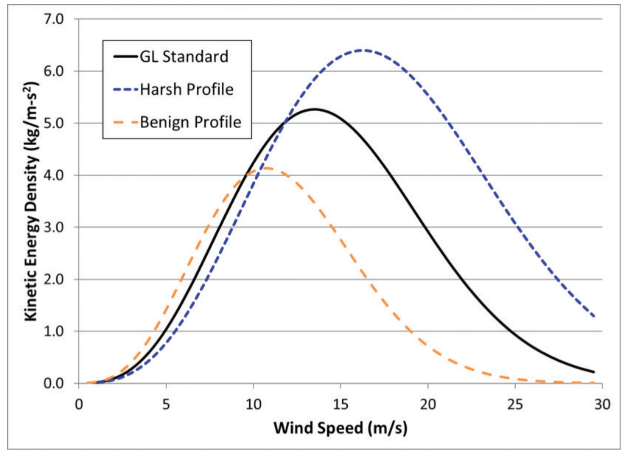

Figure 2: Kinetic energy density distribution examples

standards and guidelines define environmental operating conditions relevant to the design.

For example, a wind turbine certified to the International Electrotechnical Commission (IEC) Class IA is designed for average wind speeds of 10 m/s over its design life, among other parameters.[4] The turbine also is designed for a specific wind-speed probability distribution. The wind-speed probability distributions define the fraction of time the wind turbine is expected to experience winds of various speeds. Figure 1 shows an example distribution for a Class IA turbine from the GL Guideline for the Certification of Wind Turbines.

The actual wind-speed distribution experienced by a turbine in operation likely will be different from the certified distribution; the actual distribution will be either relatively benign or relatively harsh. A distribution that is relatively benign compared to the design distribution will have more low-speed winds and fewer high-speed winds, as shown by the orange curve in the figure. Conversely, a distribution that is relatively harsh will have fewer low-speed winds and more high-speed winds, as shown by the blue curve.

EFFECTS OF THE WIND

The actual wind speeds experienced by a turbine can be determined through analysis of the historical environmental operating conditions at the site, which often can be acquired from the site-specific archived SCADA data and from local meteorological systems. From the comparison of the actual-versus-design wind speeds, a qualitative determination of the wind-speed margin between the actual and design conditions can be made, showing whether the winds at the site have been relatively benign or relatively harsh.

To quantify the margin between the design and actual conditions, the cumulative effects of these winds can be assessed by quantifying the kinetic energy density associated with the winds. The kinetic energy density is a calculated measure of kinetic energy in the wind per unit volume of air. It is equivalent to the dynamic pressure applied to a structure, which results in stresses within that structure, and is a function of the air density and square of the wind speed.

Figure 2 shows a sample plot of kinetic energy densities resulting from the same wind-speed distributions shown in Figure 1. From this curve, the cumulative kinetic energy density is computed for both the design wind-speed distribution and the actual distribution from the site. Examining the ratio of these quantities provides a quantitative metric to compare the effects of the actual and design/certification wind conditions. Further specific structural analysis involving aeroelastic modeling can be pursued as needed.

Wind turbines are designed to withstand wind turbulence in addition to normal winds. For example, the IEC defines a Class IA wind turbine to be designed to withstand a turbulence intensity of 16 percent at a wind speed of 15 m/s over its design lifetime.[5] Turbulence intensities can be computed from wind data recorded at the wind-turbine site and are compared with the design values, providing another metric for quantifying the margin between design and actual wind conditions.

ENVIRONMENTAL EFFECTS BEYOND WIND

The effect of the environment on wind turbines is not limited to wind. Solar radiation, humidity, and airborne salinity can have a deleterious effect on the turbine's materials. For example, high levels of ultraviolet exposure can cause degradation of organic materials. The GL guidelines[6] list a design solar radiation intensity value of

1,000 W/m^2, which is a particularly high value. Comparisons between this value and the historic site conditions provide further quantification of the turbine's environmental condition margin.

Like other machines exposed to the environment, wind turbines contend with the effects of corrosion. Rainfall, humidity, and airborne salinity, along with material susceptibility, affect the potential for corrosion. For example, a wind farm by the ocean is more likely to experience airborne salts stirred up by the sea, whereas the quantity of salt in the atmosphere in inland locations will generally be decreased. Design parameters for these corrosion-related items can be found in design certification documents, including the design certificate itself in some cases. Analysis of these conditions, as with that of wind and solar radiation, helps to identify margins between the environmental operating conditions and the design conditions.

FURTHER CONSIDERATIONS

Beyond the comparison of historical versus design conditions, further analyses can be used to assess continued operation. One option is to analyze the historic availability of the wind turbines of interest, which measures the fraction of time a wind turbine is available for use. These data are used to identify trends, such as increasing amounts of downtime, experienced by a wind turbine as it ages. Additionally, statistical analysis of the data can identify trends that can predict if/when the availability will drop beneath a stakeholder's acceptable threshold.

Additionally, to help inform expectations of operating life, publicly available information related to the specific wind-turbine model can be reviewed, with the goal of gathering information and operational experiences involving the same or related models installed at other locations. Specific items to consider are the installation locations of the turbine type, the number of turbines installed, reported technical issues, industry experience with the turbines, and common maintenance issues encountered. Information can be found in trade publications, databases, journal articles, and other sources.

As a wind turbine reaches the end of its design life, stakeholders can seek a lifetime extension certification. The certification procedure outlined in DNV-GL-ST-0262, Lifetime Extension of Wind Turbines, consists of both an analytical and a practical part. The analytical part comprises load calculations, reliability analysis, measurements, and other items, and the practical part comprises detailed equipment inspections, review of SCADA data, review of maintenance and availability reports, and analysis of others' experiences with similar turbines.[7]

Analyses discussed here, among others, are used to evaluate wind turbines for continued operation. Such analyses can assist stakeholders in a variety of business decisions throughout the life of the turbine.

ACKNOWLEDGEMENTS

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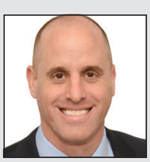

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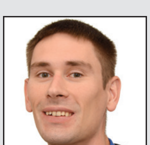

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