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LABORATORY WEATHERING DEVICES

实 验 室 老 化 设 备

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摘要: 介绍人工老化试验设备中最常用的几种光源的产生、发展、结构和特点,并从与自然光源相似程度的角度,分析了几种光源的优缺点。

关键词: 老化; 设备; 光源

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Abstract:

The history, structure and characteristic of four light resources mostly used in laboratory weathering has been described. At the same time their limitation are discussed.

由于需要比室外自然老化测试较为快速地评估材料的抗老化性能,以及需要可控的测试环境,通常采用带人工光源的测试设备来加速老化过程。这些设备包括碳弧灯、过滤的氙弧灯、金属卤化物灯和荧光紫外线灯。这些"试验室加速老化"测试设备在某些情况下可能最适合于"人工老化"试验工作。

"实时"老化加速方法的采用有几个原因。首先,这种测试可以在自然的或比日光更强的辉光下工作,不受日常循环、季节变化和气候条件的影响。材料暴露的温度、热循环、湿度和水份也可以控制到最大值,但是不会影响应力问题。样品可以暴露在超过自然水平的光谱能量下,虽然在

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Due to the need for more rapid evaluations of the resistance of materials to weathering than can be obtained by outdoor exposure tests and the need for controlled conditions, test devices with artificial light sources are generally used to accelerate the degradation. These devices include carbon arc and filtered long arc xenon, metal halide and fluorescent UV lamp apparatus. These "laboratory accelerated weathering" device tests are sometimes, and perhaps more appropriately, referred to as "artificial weathering".

The acceleration over "real time" weathering occurs for several reasons. Principally, the tests can run continuously at naturally occurring or higher irradiance than solar radiation, uninterrupted by the diurnal cycle, seasonal variations and weather conditions. Temperatures, thermal cycles, humidity and water exposure can also be manipulated to maximum but not unrealistic stress levels. Specimens can be exposed to spectral energies at or beyond the limits of their intended service exposures, although caution must be exercised so as not to induce unnatural degradation mechanisms.

此过程中必须仔细操作,以防止产生非自然的老化机制。

除了可以根据要求加速和控制老化条件的能力,实验室测试的另一个主要优点是其精确性和可重复性,而在自然测试中,实际气候是无法控制的和多变的。另外,每个老化因素都可以独立控制,这样,研究工作可以简化为研究各种老化条件对材料性能的特定影响,而这是在户外的自然条件下很难或无法进行的。

人工老化设备通常按照使用的光源类型分类。最常见的光源类型有碳弧灯、荧光紫外线灯以及金属卤化物光源。每种光源都有自己的优点及缺点,每个老化实验人员都必须懂得这一点。由于曝露材料所吸收的辐射能是至关重要的,我们将着重讨论光源的质量,即每种光源与自然日光的相似程度。

碳弧灯

碳弧仪器最初被德国合成染料化学家用来评估被染纺织品的耐光度。第一台阿特拉斯 Color Fade - Ometer® 于 1919 开始投入使用,作为一种封闭式碳弧(ECA)光源,它是在以前的一种阿特拉斯产品上重新设计开发的。前一种产品本身是在更早的阿特拉斯日光碳弧舞台灯基础上开发的。当时芝加哥是世界电影之都,而舞台灯光正是阿特拉斯的主要业务。对于这种舞台灯光的使用者来说,演员所穿的某些纺织布料和衣饰会逐渐掉色。今天,封闭式碳弧灯有单弧和双弧两种;电弧封闭在一个 Pyrex™ 球中,这个球可以具有某些过滤功能,并可提供一个无氧环境。

1930 年发明了一种开放式碳弧灯,即带 Corex® 过滤的阿特拉斯日光碳弧 Weather - Ometer® ,它可以比自然日光提供更多的

In addition to the ability to manipulate and accelerate weathering conditions on demand, a fundamental benefit of a laboratory test is the precision and repeatability over what is essentially an uncontrolled and variable phenomena, the actual weather. Plus, each of the weathering factors can be manipulated independently; thus research can be conducted into the specific response of materials to various weathering factors, experiments which would be difficult or impossible to conduct outdoors.

Artificial weathering devices are often categorized by the type of artificial light source used. The most common types are carbon arc, fluorescent UV, xenon - arc, and metal halide light sources. Each has it's own inherent benefits (and pitfalls) of which a weathering experimenter must be aware. Since the radiant energy received by an exposed material is considered the most important, we will focus our attention on the quality of the light source, referring to how well each light source resembles natural sunlight.

Carbon Arc Sources

The carbon arc instrument was first used by German synthetic dye chemists to evaluate the lightfastness of dyed textiles. The first Atlas Color Fade - Ometer® , introduced in 1919, used an enclosed carbon arc (ECA) light source. Its development was a result of a redesign of an earlier Atlas unit, the Solar Determinator. This earlier development itself was an outgrowth of Atlas' Solar - Light carbon - arc stage lighting, Atlas' main business during the days when Chicago was the motion picture capital of the world. It became apparent to the users of this stage lighting that certain textile materials and garments worn by the actors would fade after extended lengths of time. Today, enclosed carbon arcs are available in single and twin arc versions; the arc is enclosed in a Pyrex™ globe to provide some optical filtering and an oxygen - deficient atmosphere. The introduction in the 1930's of the open flame carbon arc, in the Atlas Sunshine Carbon Arc Weather - Ometer® with Corex® filters, provides more UV < 300nm than sunlight but gives a much better match in the 300 - 340nm region and deviates less than the enclosed carbon arc at longer wavelengths. When used without

波长小于 300 nm 的紫外线,但是在 300 nm - 340 nm 波段上更接近自然光,并且比封闭式碳弧灯在更长的波段上的偏离性更小。如果不使用过滤装置来进行更快速测试,那么与户外自然测试相比,某些材料的稳定性可能发生变化。日光碳弧灯使用三对碳棒,不受空气流动的影响,电弧在碳棒之间旋转,以模拟每天的日光变化,弧光由周围的平面 Corex 滤镜组过滤。

这种灯的紫外线光谱与日光相差较大。它的两个强力发射波段峰值分别在 358 nm 和 386 nm,是日光强度的 4 倍和 20 倍。对于只吸收短波紫外线辐射的材料来说,这种光源比日光的老化效果要弱,但是对于既吸收长波紫外线又吸收可见光的材料来说,这种光源的效果要比日光强。所以,对于评估材料的相对光稳定性来说(既包括吸收短波紫外线的材料,也包括吸收长波紫外线的材料),与暴露在日光下的老化结果相比,封闭式碳弧灯的结果可能会不准确。

这两种碳弧技术都需要每日更换碳棒和清洁球罩的滤镜。滤镜和球罩老化很快,必须定期更换。同时,必须清除累积的碳灰。使用碳弧灯的历史时间很长,至今在某些测试中仍旧使用这种光源。而且对于某些材料来说,这种灯的效果与日光的效果很近似。现在,这种技术已经被氙弧所代替。描述使用碳弧光源的设备性能的主要文献是:

ISO 4892 - 塑料 - 实验室光源的方法 - 第四部分:开放式碳弧灯,ASTM G152,使用开放式碳弧光源照射非金属材料的操作方法以及 G153,使用封闭式碳弧光源照射非金属材料的操作方法。

荧光紫外线光源

四脚长荧光紫外线灯与家用和商用照

filters for faster testing, stability rankings of some materials may be distorted when compared with outdoor testing. The Sunshine arc uses three pairs of cored carbon rods and operates in a free flow of air; the arc is rotated among the pairs to provide approximately a day's operation per set and the arc is usually filtered by flat Corex filters arrayed around the arc.

The spectral emission in the UV bears little resemblance to daylight. Two strong emission bands, peaking at 358nm and 386nm are about 4 and 20 times daylight respectively. This type of light source can be expected to have a weaker effect than solar radiation on materials that absorb only short wavelength UV radiation, but a stronger effect on materials that also absorb long wavelength UV and visible light. Therefore, in trying to evaluate the relative light stabilities of materials, some of which absorb only short wavelength UV and others that also absorb long wavelength UV, the enclosed carbon arc could distort the rankings when compared with samples exposed to solar radiation.

Both carbon arc technologies require daily replacement of the carbon rods and cleaning of the filters or globes. Filters and globes degrade and must be periodically replaced; accumulated carbon soot must also be removed. There is a vast amount of historical data using carbon arcs, and a number of test methods still specify their use. While good correlation with outdoor exposures has been reported for some materials whose weathering mechanisms are appropriate for these limited spectrum sources, this technology has largely been replaced with xenon arc instruments. The primary documents describing performance characteristics of devices that use the carbon arc light source are: ISO 4892 - Plastics - Methods Of Exposure To Laboratory Light Sources - Part 4: Open - Flame Carbon - Arc Lamps, ASTM G152, Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials and G153, Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials.

Fluorescent UV Sources

Four - foot long fluorescent UV lamps, similar to those used for residential and commercial lighting,

明一样,也具有特定光谱段。这些光源使用了荧光紫外线聚光技术。可用于亮/暗循环变化、温度、湿度和喷水的变化环境中。这种设备的功能设计和使用方法主要由 ISO 4892 规定 - 塑料 - 实验室光源的方法 - 第三部分:荧光紫外线灯以及 ASTM G154,用于非金属材料的荧光紫外线设备的操作方法。

荧光 UVB 灯 (F40 和 UVB - 313) 的峰值波长在 313 nm 左右,其能量几乎全部集中在 280 nm 到 360 nm 之间。其能量分布的波长范围比日光的要短,在 360 nm 以上几乎没有什么能量。在使用这种 UV - B 灯进行加速老化实验时,所得到的被测材料稳定性经常与户外自然测试中的数据差异较大。这是因为这种光源的短波紫外线能量比例很大,并且缺少长波紫外线和可见光部分的能量。在这种光源下,材料老化的机理可能与“自然”测试中相差很大。

荧光黑灯即 UVA 灯,其射线波长主要集中在 340 nm 到 370 nm 之间(例如 UVA - 340 和 UVA - 351)。UVA - 340 灯发明于 1987 年,其短波辐射与 325 nm 以下的日光直射很相似。UVA - 351 的短波光谱分布与透过窗玻璃的日光相似。

由于 UVA 灯不发射陆地日光波长以下的高能辐射,所以在使用这种光源的测试效果更接近自然老化,但是测试的时间比 UVB 灯要长。为了缩短测试时间,可以结合使用 UVB 和 UVA - 351 灯。但是,由于 UVB 灯具有过多短波射线(在陆地日光波长范围以下),而 UVA 灯缺少长波辐射,所以其模拟效果不佳。但是,需要指出的是,利用这种灯的测试还是很多的。如果想相对地比较不同材料在特定条件下的抗

have been developed with specific spectral distributions. These sources are incorporated into fluorescent UV condensation. These devices may be used in cycles that may vary light/dark cycles, temperature, condensing humidity and water sprays. Their functional design and use is primarily governed by ISO 4892 - Plastics - Methods Of Exposure To Laboratory Light Sources - Part 3: Fluorescent UV - Lamps, and ASTM G154, Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.

The fluorescent UVB lamps (F40 and UVB - 313) with a peak around the 313nm mercury line, has nearly all of its energy concentrated between 280nm and 360nm. A large fraction is at wavelengths shorter than those present in sunlight and it has very little energy longer than 360nm. Reversals in the stability ranking of materials have often been reported between laboratory accelerated and outdoor tests when the accelerated test uses UV - B. This is due to the predominance of short wavelength UV and the deficiency of long wavelength UV and visible radiation; the mechanisms of degradation may be significantly different from those of the "natural" test.

Fluorescent black lights, referred to as UVA lamps, are available with peak emissions of 340nm - 370nm (e.g., UVA - 340 and UVA - 351). In the UVA - 340 lamp, developed in 1987, the short wavelength irradiance simulates that of direct solar radiation below 325nm. The UVA - 351 spectral distribution at lower wavelengths is similar to that of daylight filtered through window glass.

Because the UVA lamps do not emit high energy radiation below the cutoff of terrestrial solar radiation, correlation with outdoor weathering is somewhat improved but test times are longer than with UVB lamps. Combinations of UVB and UVA - 351 lamps have been used to provide shorter test durations than can be achieved with either lamp alone. However, because of excessive short wavelength radiation in the UVB lamp (extending well below the terrestrial cutoff around 300nm) and the lack of long wavelength radiation with the UVA lamp, this is also not a good solar simulator. It may be noted, however, that tests utilizing these lamps are widely practiced. These tests

老化性能,那么这种灯还是很有用的。但是无法预测材料的使用寿命和与自然条件的对应关系。这种灯最适合用作通用放映工具,例如,使用人工粗侧检查总体公式错误等。

总之,这些设备为潮气模拟提供了凝结变化过程(在无光情况下)。测试表面暴露到一种空气和水蒸汽的加热饱和混合环境中(在黑暗情况下,相对湿度几乎达到 100 %),而测试板的背面暴露到正常空气中,这样,板的温度会降到露点以下,导致在此面上形成水珠(露水)。紫外线变化过程和凝结过程都的顺序和时间都可人工调整并实现自动控制。同样地,在紫外线和凝结变化过程中,温度也可控制(在一定范围内)。

氙弧光源

第一台使用氙弧灯的老化设备发明于 1954 年(Xenotest® 150)。自从 1960 年在北美应用以来,氙气长弧灯得到了广泛使用,这种灯光经过过滤后,与日光光谱最接近。与电燃烧开放式碳弧不同的是,氙弧是一种精确的气体放电灯,它使用石英球罩密封。使用过滤技术可以精确调节其光谱能量分布,这样,可以模拟各种条件下的自然光,从大气层外的日光到透过玻璃窗的日光等等。所以,对于需要使用自然阳光条件的材料测试,使用这种光源模拟是比较理想的。水冷却氙弧技术在汽车和纺织工业中使用很广泛,它替代了碳弧技术,虽然碳弧设备从 1950 年以后很难再见到,但是以前是一种经常应用的技术。

与碳弧设备无法控制光强度的情况不同的是,现代的氙弧设备不仅可以通过光学过滤控制能量的光谱分布,还能通过调节电功率控制辉光。在氙弧技术发展过程

may be useful for relative rank comparisons between materials under specific conditions; however the extrapolation to service lifetime performance or correlation to outdoor exposures may not be valid. Their best use may be as general screening tools, e.g., checking for gross formulation errors with an artificially harsh test.

In general, these devices offer a condensation cycle (during a lights - off period) for moisture simulation. The test surface is exposed to a heated, saturated mixture of air and water vapor (relative humidity approximately 100 % during the dark cycle) while the reverse side of the panel is exposed to room air which cause the panel temperature to drop below the dew point. This causes water droplets (dew) to form on the exposed surface. The sequence and time intervals for both the ultraviolet cycle and the condensation cycle are programmable and automatic. Likewise, temperatures can be controlled (within limits) during both the UV and condensation cycles.

Xenon Arc Sources

The first weathering machine using a xenon - arc lamp was developed in 1954 (Xenotest® 150). In use in North America since the 1960's, the xenon long arc, when properly filtered, more closely simulates full spectrum solar radiation than any other artificial light source. Unlike the electrically burning open carbon arcs, the xenon arc is a precision gas discharge lamp in a sealed quartz envelope.

The spectral power distribution can be finely tailored through filtering to simulate solar radiation ranging from above - the - atmosphere through to sunlight - as - filtered - through - window - glass. As such, it is widely preferred as a light source when the material to be tested will be exposed to natural sunlight. Water cooled xenon has been extensively adopted by the automotive and textile industries, and is generally replacing carbon arc technology as those units age, although it is not uncommon to find carbon arc devices from the 1950's, and earlier, still in regular use.

Unlike the carbon arc exposure devices, which had virtually no control over the light intensity, modern xenon apparatus exercise precise control over both

中,出现了两种仪器系统:风冷和水冷氙弧设备。冷却类型对设备的总体设计和光学过滤系统都有影响。阿特拉斯 Fade - Ometers®和 Weather - Ometers®只使用水冷氙弧,而小型的阿特拉斯 Suntest®CPS 和 XLS 台式系统使用风冷氙弧灯。ISO 105 - B02,纺织品 - 褪色测试 - 人造光下的褪色:氙弧褪色灯测试,ISO 4892 - 塑料 - 实验室光源方法 - 第二部分:氙弧光源,以及 ASTM G155,用于非金属材料的光照设备操作指南是这些仪器性能要求的基本标准。

根据仪器的设计,样品可以放置在垂直或水平位置上。对于大型的设备,主要使用垂直方式。两级或三级倾斜样品架可以保证辐射的一致性。如果想达到更好的一致性,或者需要其它功能(例如喷雾),整个样品架可由一台马达推动,以每分钟 1 圈的速度旋转。对于高辐射测试,Ci5000 Weather - Ometer®可以每分钟旋转 10 圈。

水冷氙灯是由两块同轴圆柱形光学滤镜围住的一个密封石英管。冷却水在灯表面、内滤镜和外滤镜之间流动。除了冷却功能,水还对红外线光谱范围产生所需的效应。水吸收了 1200 nm 波长以上的光线,减少了氙灯中过多的红外线能量。这种减少足以保持样品温度稳定;使用红外线吸收滤镜还可以进一步减少红外能量。

未过滤的氙弧在短波紫外线区的辐射能力很强。因此,滤镜的主要目的是获得所需的能量光谱分布。通过综合水冷系统的两个圆柱形滤镜的不同玻璃特性,可以产生不同的光谱能量分布。可用的圆柱形滤镜类型有石英、硼硅酸盐玻璃、高硼酸盐

the spectral distribution of energy through optical filtering as well as irradiance control by way of electrical power management. In the course of xenon arc development, two instrument systems have emerged: air - cooled and water - cooled xenon instruments. The type of cooling has an influence on the overall design and on the optical filtering system. Atlas Fade - Ometers® and Weather - Ometers® use water - cooled xenon arc exclusively; the small Atlas Suntest® CPS and XLS table top exposure systems use an air - cooled xenon lamp. ISO 105 - B02, Textiles - Tests for Colourfastness - Colourfastness to Artificial Light: Xenon Arc Fading Lamp Test, ISO 4892 - Plastics - Methods Of Exposure To Laboratory Light Sources - Part 2: Xenon - Arc Sources, and ASTM G155, Practice for Operating Xenon Arc Light Apparatus for Exposure of Nonmetallic Materials are the primary standards regarding performance requirements of these instruments.

Depending on the design of the instrument, specimens may be exposed in the vertical or in the horizontal position. For large - scale equipment, the vertical style prevails. Two - tier and three - tier inclined specimen racks contribute to irradiance uniformity. For even better uniformity and when other functions are required (e.g., spraying), the entire rack is driven by a gear motor at a speed of one revolution per minute. For high irradiance tests, the Ci5000 Weather - Ometer® has an option for a 10 rpm rotating rack.

The water - cooled xenon lamp is a sealed quartz tube surrounded by two concentric cylindrical optical filters. Cooling water flows in between the surface of the lamp, the inner filter and the outer filters. In addition to its cooling function, the water also has a desired effect in the infrared range. Water absorbs from approximately 1200nm up and thus contributes to a reduction in the excess of infrared energy produced by the xenon lamp. This reduction is normally sufficient to obtain an acceptable sample temperature; further reduction can be obtained with special infrared absorbing filters.

The unfiltered radiation of the xenon arc contains considerable radiation in the short wavelength

硼硅酸盐类玻璃、碱石灰玻璃和涂层红外线吸收(CIRA)石英。加入辅助玻璃滤镜支架放置不同种类的平面玻璃后,可以实现辅助过滤。

射线量可由微处理器控制。水冷仪器可把射线强度范围控制在 340 nm 或 420 nm。射线直接穿过石英管,并使用窄波段滤镜过滤。然后,光电探测器会向功率调节器发送信号,降低或提高灯本身的功率。大型的水冷和风冷氙弧灯还有能力严格控制老化过程的其它参数,例如湿度、环境温度、和黑板(或样品)温度,同时亮/暗变化的测试和雨露喷洒模拟系统在这些装置中也经常使用。

金属卤化物光源

汽车制造商和其供应商不断采用新技术和测试方法进行试验。例如实验大型汽车部件的抗老化性能,像仪表板、车门装置和保险杠系统,以测量这些多组件复合系统的老化影响。MHG(金属卤化物全球®)电弧灯良友特殊的电源,可以提供与直射和散射非常相似的光谱能量分布。由于它们的高效性,这些光源非常使用于大型多源阵列应用,对热负载研究也是很有效的。它们主要应用于某些欧洲测试方法中(例如 DIN 75 220,汽车部件在日光模拟光照系统中的老化),并符合相应的军用测试要求(MIL - STD 810)。

需要指出的是,人工测试永远也无法与自然暴露条件完全一致。由于自然暴露条件变化千差万别,所以实验室设备(例如 Weather - Ometer®)主要用于可控的、重复

UV. Thus, the role of the filters is to obtain the desired spectral distribution. By combining different glass properties in the two cylindrical filters of the water - cooled system, it is possible to produce different spectral energy distributions. Types of cylindrical filters available include quartz, borosilicate glass, high borate borosilicate Type - S glass, soda lime glass and Coated InfraRed Absorbing (CIRA) quartz. Additional filtering is possible by adding an auxiliary glass filter holder to accommodate the wide variety of filters available in flat form.

Radiation dosages are microprocessor controlled. The water - cooled instruments control the intensity of radiation at 340nm or 420nm. The light is directed through a quartz - lined tube and filtered with the desired narrow - band interference filter. A photodetector then sends a signal to a wattage regulator to raise or lower the power to the lamp itself. Large scale water - cooled and air - cooled xenon arc instruments also have the ability to tightly control other parameters in the weathering processes, such as humidity, ambient temperature, and black panel (or specimen) temperatures. Test cycles for light - dark cycling and spray delivery systems for rain and dew simulation are commonly utilized.

Metal Halide Sources

The automotive manufacturers and their suppliers continue to experiment with new technology and testing approaches. This is exemplified by efforts to expose large components such as instrument panels, door assemblies and bumper fascia systems to gauge the effects on stressed and formed multi - component systems. MHG Metal Halide Global® arc lamps with special power supplies provide spectral power distributions that closely match direct solar plus sky radiation. Because of their high efficiency, these sources are ideally suited for use in large scale multiple source arrays and are effective for thermal loading studies. They are used in some European test methods (such as DIN 75 220, Aging of Automotive Components in Solar Simulation Units) and comply with certain military testing requirements (MIL - STD 810).

It is important to note that no artificial test can ever precisely duplicate outdoor exposure conditions. Since outdoor exposure conditions can and do vary greatly, the use of laboratory devices such as the Weather - Ometer® are primarily for the controlled,

性的、可重现的和技术允许的条件。实时老化的加速是一种副产品,但是不太重要。虽然对于许多材料来说,很多测试方法的结果与自然户外老化(例如南佛罗里达和亚利桑那中部)结果非常相近,但是仍然无法等同。它们的主要作用是为材料比较提供一种一致的基础。在实时老化测试得到验证以前,这些测试方法中得到的结果可用于评价材料性能。

repeatable and reproducible conditions that the technique affords; any acceleration over real - time weathering is a bonus, but of secondary importance. While many test methods have shown good correlation to outdoor weathering (e.g., south Florida and central Arizona) for many materials, they do not purport to be equivalent. Their main value lies in providing a uniform basis for material comparison. Results obtained under these test methods are generally accepted for material performance evaluation until the real time weathering tests are validated.

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