LED Lighting

MASTERY STATEMENT:

In this module you will learn how LED lamps work and the benefits of this technology.

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LEDs

LED lighting is the latest in a long line of lighting technologies that started with open flame and progressed through various technologies including incandescent, fluorescent, and halogen. The 19th Century brought filaments in a vacuum which introduced the incandescent lamps. The 20th Century brought us gas discharge lamps such as fluorescent and HID lamps. The 21st century brought us solid state lighting which introduced the light emitting diode, or LED.

Light emitting diodes compared to their predecessors, are more robust, more economical over time, longer lasting, and brighter for a given amount of electric current.

(Hours of Service)

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<th>Fluorescent</th>
<th>Incandescent</th>
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An LED (Light Emitting Diode) is a simple two-post device called a diode that emits light when an electrical current is passed through it. Unlike incandescent lamps, the LED has no filament. Instead, its design includes two metal posts, one positive and one negative, which are placed in close proximity. Materials within the LED convert some of the current that runs between the two posts into photons of light in the red end of the light spectrum. To protect and enclose the system, the LED to the right is covered by an epoxy casing that totally encapsulates the device, and gives this style LED its recognizable bell shape. LEDs are available in many different shapes and sizes, that will be covered later in this module.

LED Color

The color of an LED is dependent on the materials used in its construction. Early LEDs were capable of only emitting infrared and red light because they were manufactured using gallium. Newer LEDs are available in a variety of colors. They are more expensive because the chemical elements used in their manufacture are more costly than those used to make a “standard” red.

LED Color Temperature and Contrast

LEDs’ color temperature and contrast is closest to natural sunlight.
Lamp Efficiency Vs. Source Efficiency

A Gas Discharge light source, such as HID lamp, is actually more efficient than an LED light source. However, a gas discharge source emits light in all directions. LED sources emit light in one direction. The result is an LED lamp can be as efficient or even more efficient as a gas discharge lamp by aiming the light where it is needed.

LED Light Sources

Inorganic light emitting diodes use silicon, gallium, or other non-polymer materials. Organic light emitting diodes use polymer materials. Both technologies generate light through a diode junction, called a p-n junction. When electrons pass through this junction, a photon of light is generated. While organic LEDs show high volume manufacturing potential, the industry still struggles with creating robust and environmentally sound solutions. Therefore, the transportation industry typically uses inorganic LEDs.

LEDs are fabricated onto an inorganic substrate. The interaction of the various layers with current create the light photons. The chemical composition of the layers create the specific color of light.

LED ENGINEERING AND TECHNOLOGY

Reflecting our long history of engineering and technology excellence, Grote Industries’ investment in LED technology has steadily increased. Our continuing investment in engineering equipment and associated personnel has resulted in Grote’s leadership in introducing LED technology into the market.

Grote’s continuing investments in engineering and technology have lowered the cost of LED products and assured that these products meet market requirements. Grote has pioneered new methods of modeling, testing, and manufacturing, and LED products.
Grote constantly monitors both the market and the industry for new lighting technology and application methodology. Our monitoring includes learning about and factoring in customer and market concerns as soon as they are identified. Lighting Technical Specialists are Grote’s eyes and ears in the field and are essential in the communication of new information to our engineering group.

New technology, however, is also shared with our engineering group by suppliers of new materials and components. Trade shows, trade publications, news articles, and internet entries are monitored for new lighting technology and materials. Sometimes a technology may be reported years or decades before it becomes commercially viable. Throughout this development stage, Grote engineers and scientists track the progress of a given technology and look for opportunities to apply their knowledge to new products or processes.

**CAD & CAE**

Computer technology has changed the fundamental approach to engineering. Low cost computing power makes higher capability tools available to more designers. Two terms used frequently are Computer Aided Design (CAD) and Computer Aided Engineering (CAE). These two techniques speed the development of new products by using computers to model and build lamps inside the virtual world before they are actually produced.

**Computer Aided Design (CAD)**

Computer Aided Design (CAD) was first developed to replace the drafting table. Just as a part was represented on paper by drafting various views, the first CAD systems simply replaced the paper of the drawing board with the image on a monitor’s screen. The computer was an easy way to make changes to the “paper drawings”. This was known as two dimensional (2-D) CAD. As CAD software improved, features that allowed the designer to stretch, cut, and move objects around allowed faster changes to existing designs. It was not long before software allowed designers to add thickness to parts, leading us to three dimensional (3-D) CAD.

Today any design can be modeled in three dimensions within a computer. Grote Engineering can import sections of a vehicle and design a lamp to fit in a cavity, assuring fit before the part is tooled.

As models of parts within the CAD system became more complex, so did the drawings that described those parts. The industry has now evolved to the point where any given part is defined by the 3-D model of it in the computer, not just a paper drawing of it. In fact, when a plastic mold tool is ordered, the CAD model is sent to the tool shop and the tools are created from the model. This CAD data is transferred on the internet via an FTP site. The term FTP stands for “file transfer protocol” which is an industry standard protocol that allows data to be transferred between companies.

The complexity of the CAD software is also driven by the complexity of the model. Some models, like simple brackets, grommets, harnesses, or housings can be defined with little information. Parts with optical surfaces, like lenses and reflectors, are usually defined using more complex mathematical equations. Software that can manage such an accurate definition of every small detail requires greater computation memory and power.
**Computer Aided Engineering (CAE)**

Once parts could be modeled within a computer, new software that modeled specific characteristics followed. The field of study that used software to check these specific characteristics is called Computer Aided Engineering, or CAE. CAE attempts to model the real world in the computer. It allows “what if” scenarios without tooling or building a part.

Some of the CAE software tools that are used in Grote products include Mold Flow, Finite Element Analysis, and Thermal Modeling. Mold Flow models the flow of plastic resin into a tool. It predicts problem areas where gas may get trapped within the tool, or where plastic may improperly flow together, creating an undesirable cosmetic defect. Finite Element Analysis models the stresses experienced by a part, highlighting weak points in a mechanical design before it is tooled. Thermal Modeling predicts the heat flow within a lamp, illustrating the temperature rise in components and LEDs. Each software package requires a significant amount of time and skill to set up the parameters of the model. It also requires time and skill to review the data to assure nothing was incorrect in the software assumptions.

**OPTICS**

An area of modeling that is key to the performance and cost of lamps is optical engineering. This field of engineering has become more critical with the introduction of LEDs. Before LEDs, incandescent bulbs were the primary light sources for vehicle lighting. There were few standard light bulbs for the industry. Each bulb put out more light than the lamp needed. Once the investment was made in the bulb, the extra light could be used to assure a brighter pattern than required by law.

With a multiple LED based lamp, each LED in its design costs money. A lamp with fewer LEDs usually means a more competitive lamp. Therefore, the light in an LED becomes more valuable. If the light from the LEDs can be used more efficiently, fewer LEDs are needed, and the lamp is less expensive. In other words, the supplier who manages the light the best – wins!!

An example of such optical skill providing a competitive edge is the Grote Select® 4” STT (stop/tail/turn) using only three LEDs. After the launch of the Grote Select® 4” STT, the industry expressed surprise and respect that Grote Select® could get such a high output of light from only 3 LEDs.

**LAMP DESIGN**

A lamp design takes shape when the optical engineer places the lens or reflector surface at a location that directs the light where it is needed. The light must be aimed so that other drivers see the vehicle light, warning them of a stop or turn. The governmental regulations that state where the light would provide the most warning are FMVSS 108 (Federal Motor Vehicle Safety Standards 108). As the design takes shape, the optical engineer runs a simulation that traces individual light rays from the light source to their final locations in space. The more rays traced, the more accurate the model. Some models can take hours to days to run one simulation. Therefore, the more skill and knowledge the optics engineer has, the faster the design process will go.

As the optic design progresses, the lens, or reflector elements, will be passed to CAD through translation software. The translation software takes the optical modeling data and translates it into a new set of data that the 3-D CAD software can use.
CAD designer then takes those elements and builds a solid model around the lens or reflector inside the computer.

After the CAD designer is finished, the model is translated back to the optical simulation software, where the individual rays are traced with the finished model. If the model matches the regulatory or customer requirements, the optic design is complete. If the model does not match the requirements, more design work is done and the cycle is repeated.

**TESTING AND COMPLIANCE**

Compliance means that a lamp meets customer and federal requirements and is backed up with the appropriate documentation.

Grote has an internal Product Test and Evaluation (PT&E) Lab that provides test and compliance services for Grote products. The lab's capability is certified by outside auditors and organizations. The lab has all the equipment needed to test lamps and turn signal switches for SAE, FMVSS (Federal Motor Vehicle Safety Standards), CMVSS (Canadian Motor Vehicle Safety Standards) compliance.

Grote has the ability to test lighting equipment beyond that required by FMVSS. One test unique to Grote Industries is the Severe Environment Test. This test involves submerging an entire lamp and harness system in a salt water solution, vibrating it, and then cycling it on and off. Enduring one thousand hours of this test provides a good indication of system performance over the life of the vehicle. The Severe Environment Test is also used for continuous improvement of new and existing products.

**ADVANCE TECHNOLOGY GROUP**

The Advance Technology Group has specialized skills related to the technology used in Grote products. Staff personnel are assigned to project teams at the appropriate time in the development of a product.

The Group also works on high risk projects – projects that have too many unknowns in them for accurate product introduction timing. The unknowns may be related to new suppliers, new design concepts, or new manufacturing methods. Grote performs research to develop techniques, i.e., research that is done with an end product or application in mind. These high risk projects will typically result in prototypes of a concept to demonstrate feasibility, identify potential hurdles, or indicate potential new products.

One example of such a prototype that eventually became a new product line is the Trilliant LED Driving Lamp. Over a year before the launch of this product, the Advance Technology Group built 10 prototypes that ran in the Baja 1000, proving their robustness and value.

Organizations like universities and government labs also conduct research and development. This research may be decades away from commercialization, but the Grote Advance Technology Group monitors new ideas and inventions related to lighting technology for possible future products.
MANUFACTURING LEDS IN NORTH AMERICA

An LED is manufactured in a series of procedures that control many parameters such as temperature, pressure, and chemical composition. It is a very complex process, both in material and manufacturing. In spite of complex process controls, LEDs can vary from lot to lot in such key areas as color, intensity, and the voltage at which they emit light. Due to these variations, LED manufacturers separate the end product into bins based on their characteristics, a procedure known as “binning”. There are three primary bins. One is the Voltage bin identifying the voltage required to get the LED to turn on. Another bin is the Color bin where the color of the light is highlighted. The third bin is the Intensity bin which identifies the brightness of the light that the LED emits.

The electronics are designed to compensate for these variations. Grote’s electronic facility will design and select the proper components so that the finished lamp meets the color and intensity required to meet customer and government mandates.

LED lamps are more susceptible to negative voltage spikes than incandescents. Negative spikes are caused by relays, motors, and solenoids within a vehicle. Every Grote LED lamp has an electrical component called a rectifier diode that protects the LED from these negative voltage spikes.

Heat Sensitivity
One of the few disadvantages of LEDs is their sensitivity to heat. The light output of an LED drops as the device heats up, and high temperatures (above about 125°C) can permanently damage an LED. Even though LEDs are efficient they do generate their own heat, although not nearly as much as an incandescent bulb with comparable light output. This heat needs to be properly managed in order to maintain LED performance at acceptable levels.

Potting
Potting is a process of filling a complete electronic assembly with a solid compound to provide resistance to shock and vibration, as well as for exclusion of moisture and corrosive agents. Thermal conductivity is a critical parameter in the selection of a potting material for an LED because a material with high thermal conductivity will pull heat away from the LED and thereby extend its life. Grote even patented a potting technique that draws heat away from the LED to prolong its life.

Potting provides numerous benefits beyond conducting heat away from the LED. An important feature of potting is that it mechanically fastens the board assembly to the base and also seals the solder joints and terminals. A conformal exterior coating only seals the solder joints and terminals. As the amount of potting applied to a component increases, so will the time and material that will be required in the manufacturing process.

As a by-product, Grote potting provides an aesthetic white appearance to the lamp. White potting material was found to improve the aesthetics of LEDs and quickly became the preferred type of potting.

What Value Does Potting Provide?
In 2006 with more than four years of unpotted “high count” lamps out on the market at the time, Grote’s Quality and Advance Technology Group did an analysis of return data for four lamp “product families”. They concluded that the best quality lamp is a potted LED. A majority of the potted LED lamps performed much better than unpotted LED lamps or incandescent lamps. They found that removing the potting will increase the
return rate by two to five times. This return rate may actually be higher than the data indicates.

They also discovered that the user seems to get a longer life with an unpotted LED than a regular incandescent bulb because the ratio of return for an unpotted LED lamp is about two times lower than that for a regular incandescent lamp. Finally, they found that when switching from an incandescent lamp, the level of improvement is much greater using a potted LED rather than an unpotted LED.

**Pins**

In addition to potting, the Grote line of LED lamps uses solid brass terminals in male-pin and hard-shell configurations which provide a more secure connection and maximum protection against corrosion. Grote has also developed the male pin and Ultra Blue Seal® (UBS) systems to assure a sealed harness connection to the lamp. Grote uses multiple lamp connections: male-pin, female-pin, Amp style, and P2.

**LED PACKAGING**

Physically speaking, LEDs are small cubes of semiconductor material. Unlike bulbs, these components are packaged in various configurations. There are no industry standards in packaging LEDs for vehicle use.

Manufacturers have changed LED packaging throughout the years from the 5mm through-hole in the first marker lamp to the PLCC surface mount package in the G-Select. Some packages, like the Superflux package, have become a standard in the industry.

LEDs have steadily increased in intensity over the years. A lamp that once required 68 LEDs in a high count STT (stop/tail/turn) can now be manufactured with a single LED. Cost must be considered when selecting the number of LEDs to be used in a given lamp. A single LED that has the intensity of 10 Superflux LEDs may be 20 times as expensive to produce. The tradeoff between cost, looks, and the number of LEDs is unending.

![LED Flux per package has doubled every 18-24 months for 30+ Years](chart)

**Key Points**

- **Potting** protects and encapsulate the circuit board, terminals, and LEDs in epoxy. This protects the circuit board from moisture, corrosion, thermal build up, and lamp vibration.
- **Grote’s first production STT lamp** contained 68 diodes.
- **LED output** has doubled every two years for the last 30 years.
LED ADVANTAGES OVER INCANDESCENT LIGHTING

LEDs offer many distinct advantages over incandescent lighting in the trucking industry.

**Longer Life**

One of the most significant advantages between LEDs over incandescents is their superior aging characteristics and failure modes. As an incandescent bulb ages, material from the filament slowly evaporates and collects on the walls of the bulb. This darkens the bulb and lowers its light output. Eventually, enough material evaporates from the filament that it breaks and the bulb goes out.

LEDs, on the other hand, gradually decrease in output as they age, but they do so at a much slower rate than regular incandescent bulbs. Because of this extremely long life, it is impractical to define the end of life of an LED as the total cessation of light output. One commonly accepted practice is to define the end of an LED’s life as the moment when the light output drops to 70% of its initial value. Perhaps because we define LED life in terms of lumen maintenance, we tend to focus on the dimming of LEDs over time, while forgetting that incandescent bulbs do the same thing.

**LED Instant-On**

LEDs offer many advantages over incandescent lamps in terms of safety and economy. LEDs illuminate 200 milliseconds (ms) faster than incandescent bulbs. An incandescent bulb filament must heat up to achieve maximum brightness; this takes 100 to 300 ms. Further, LED lamps don’t exhibit a high in-rush current which might further delay the turn-on time. This faster turn-on time provides a safety benefit to the driver of the following vehicle. For a truck, this means a quicker braking distance response time for the vehicle following which can amount to more than a full car length of extra stopping distance at 65 mph. This instant-on time is not affected by low voltage regulation in a truck’s electrical system.

Besides their generally slower turn-on times, incandescent bulbs have the further disadvantage that their turn-on times are further increased when they are operating at lower voltages. This especially can be a problem due to the voltage drop in the wiring harness. A study by NHTSA of 546 large trucks showed that some trucks have such large voltage drops in the wiring that the voltage across the signal lamp is reduced to the range of 5.5 to 8.8 volts. By comparison, the turn-on time of LED lamps is relatively insensitive to low voltage.

**LED Shock Resistance**

Vibration and shock are conditions constantly introduced by the environment in which the product must function. Vibrations and shock can destroy or badly damage a device to the point that it must be replaced because it no longer will perform at the level intended. Products (i.e. lamps and safety equipment) that are required to comply with FMVSS-108 should be tested according to the vibration test as described in SAE J575e using the vibration test machine.

With filament based lamps such as incandescent, vibration and shock to the device can compromise the filament, the small wire suspended between two posts that glows to produce light when enough energy is applied to it. When vibration occurs or a shock is strong enough, the filament will start to swing between the two posts and will eventually break. LEDs are robust, stationary, and potted to resist shock and virtually eliminate failure due to vibration.
System Costs
LED lamps are the most cost effective in several markets when lighting maintenance costs are taken into account over the life of the lamp.

LEDs offer advantages over the use of incandescent such as:

- **System Costs**
  - Incandescent vs. LED
  - Labor/Downtime
  - Lamp Acquisition

Grote’s online ROI calculator helps measure the time cost of a lamp.

**Real Cost of Ownership**

**10 Years Service Cost**

- Labor = $11.25 ($45/hr @ 15min.)
- Downtime = $30.00 (1/2hr @ $60/hr)
**LEDs and Fuel Savings**

In a vehicle, every watt of power must be generated and supplied by the engine. Even electrical components, which are connected to the battery, eventually receive their power from the engine running on the fuel tank. Even small electrical loads eventually add up to gallons of diesel fuel.

It is important to remember that lower amp draw helps to extend the life of the battery and charging system. The following calculations provide the logic and rationale for deriving the fuel savings that a vehicle would realize by switching from incandescent to LED lamps.

**Tail/Park Lamps**

Looking first at the tail function, let us assume that for one year each light is operated for 4 hours per day for 240 days per year. This would result in 960 hours of operation per year. This number is assumed since most of the lights manufactured by Grote are for the heavy truck market.

Each LED Stop/Tail/Turn (STT) in the tail/park mode typically takes 0.04 Amps. The corresponding STT incandescent lamp takes 0.48 Amps. The current savings is 0.44 Amps. At 12.8 Volts (the industry standard for lamp design voltage for vehicles), the power savings is (0.44 Amps) x (12.8 Volts) = 5.6 Watts.

Operating at this savings for one STT for 1 year (960 hrs x 5.6 watts) results in an energy savings of 5.4 KW-hrs/year. Multiply that over 1.5 million Grote STT lamps produced in one year, and the energy savings is 8100 MW-hrs.

**In summary:**

Incandescent lamps can have over 12 to 1 ratio in power consumption over an LED lamp. An LED STT in tail mode has a 0.04 amp draw. An incandescent STT in tail mode has a 0.48 amp draw.
Brake/Turn Lamps
Looking at the brake and turn functions, these lamps function, on average, 5% to 24% of the time, depending upon the amount of city or highway driving. This calculation will use a 5% function time, since the primary market is the truck-trailer market. Each LED STT typically takes 0.24 Amps in the brake/turn mode. The corresponding STT incandescent takes 2.1 Amps. The current savings is 1.86 Amps. At 12.8 Volts (the industry standard for lamp design voltage for vehicles), the power savings is (1.86 Amps) x (12.8 Volts) = 23.8 Watts.

Operating at this savings for the brake/turn function for one STT for one year results in an energy savings of 1.1 KW-hrs/year. Multiply that over 1.5 million Grote STT lamps produced in one year, and the energy savings is 1,650 MW-hrs.

In summary:
An LED STT in turn or brake mode has a 0.24 amp draw. An incandescent STT in turn or brake mode has a 2.1 amp draw.

Marker Lamps
There is a wide range of marker lamps. The current requirements for LED marker lamps range from 0.06 to 0.1 Amps. Incandescent marker lamps range from 0.27 to 0.66 Amps. For the sake of this calculation, the difference between the highest rated LED lamp and the lowest rated incandescent lamp will be used (0.27 Amps – 0.10 Amps = 0.17 Amps). This would provide the minimum energy savings for the conversion of incandescent to LED marker lamps.

Following the same sequence of calculations as the STT lamps, one LED marker lamp would save at least 2.2 Watts. Using the one year of operation provides an energy savings of 2 KW-hours/year. Multiplied by 1.2 million marker lamps per year, the savings comes to 2500 MW-hrs/year.

In summary:
Incandescent lamps can have over 12 to 1 ration in power consumption over an LED lamp. An LED marker lamp has an amperage draw range from 0.06 to 0.1 amps
An incandescent marker has an amperage draw range from 0.27 to 0.66 amps

Typical Trailer Configuration
Below is a typical configuration on a standard dry-van trailer. This chart shows the lamp type, number of lamps required for the function, and the total amperage of that series of lamp for both incandescent and LEDs.

<table>
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<th>Lamp Type</th>
<th>Typical # of Lamps</th>
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<th>LED Lamps X AMPS (Part Number)</th>
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<td>Typical In-Rush</td>
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<tr>
<td>Current (Cold Filament)</td>
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RED AND AMBER LEDS
Red and amber LED technology is more established than for white light LEDs. Much of the recent development related to red and amber LED lamps involves the creation of smaller and more competitive lamps. For example, compare the first LED marker light introduced in 1989 to the round MicroNova® Dot. This technology focuses on packaging the LEDs, working with the supply chain, and developing new manufacturing processes. The electronic assembly methods have migrated from through-hole components, to surface-mount components, and now to laminated film lighting, such as Grote’s LightForm™.

5mm LED Package (Through-hole mount)  Superflux LED Package (Through-hole mount)  PCCL LED Package (Surface mount)  LightForm™ (Laminated lighting)

**WHITE LIGHT LEDs**

The proliferation of white LEDs has exploded in the last decade. White LED lighting can be generated by mixing different colors of LEDs, or by using a blue LED and coating it with a phosphor that changes the color to white. The later technique is used for Grote white lighting. The electronic controls needed to mix various LED colors to get white light are more expensive than a phosphor-coated blue LED.

The first white light LED Grote product was a dome lamp for use in a refrigerated trailer. For years before the LED revolution, the refrigeration dome lamp business was dominated by a fluorescent lamps that worked in the cold. One disadvantage to those fluorescent lamps was the relatively short life of the fluorescent tube due to the vibration in the trailer. LED dome lamps were a natural replacement. LEDs provide superior operation in the cold and are immune to the negative effects of vibration.

**Key Points**
- LEDs operate better in the cold and are immune to the affects of vibration.
- Currently Grote utilizes blue LEDs and phosphor to create white LEDs.

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Red + Green + Blue LEDs  Blue LED + Yellow Phosphor

The two most common methods to produce white light with LEDs.

Work lamps were the next product line launched. These lamps are getting brighter and
the cost per lumen of output is dropping. Grote constantly introduces work lamps in more sizes, shapes, and features.

**THE GROTE LED PORTFOLIO**

**High Performance**
The Grote SuperNova® line represents the state of the art in LED lighting technology. The SuperNova® line of lamps is the first choice of the performance minded OEM and fleet professional. No other lighting manufacturer delivers the combination of engineering and innovation that Grote does. No one builds a more resilient or longer lasting LED product.

SuperNova high performance LED lamps feature specially formulated encapsulant potting that seals out moisture and dirt, improving reliability and longevity. They are also sealed with a hermetic lens-to-housing seal that prevents moisture intrusion.

SuperNovas require on average 1/8th the amperage needed to drive an incandescent lamp and use diodes that are rated up to 100,000 hours. They also include solid brass terminals in male pin and hard shell configurations and are therefore more secure and provide maximum protection against corrosion. Naturally, they fit all Grote brackets and grommet mounting options. They are also lightweight, and the new NextGen™ lamps weigh 50% less than the major competitor lamps.

SuperNova LEDs come with a 10-year warranty when configured with male pin or hard shell connectors, or a 3-year warranty when configured with hardwire connectors

**High Style**
The Grote Hi Count® LED line offers a premium style choice for those who believe that ‘the more diodes the better’. The Hi Count series has become famous for bright, multi-diode lamps.

Along with maximum diode count, Grote Hi Count® LEDs offer premium styling and are the highest visibility lamps around. Hi Count stop/tail/turn lamps accept all popular incandescent plug-in connectors and fit all popular mountings and grommets. Hi Counts come with a 2-year warranty and come with standard female-pin terminations.

**High Value**
For the price/performance buyer, Grote has engineered the Grote Select® LED lamp line. The Grote Select® line offers a compliant and reliable vehicle lighting collection that provides the most value of any U.S. made LED product on the market today. They feature standard female pin connectors that save money for the customer by making it simple to retrofit old incandescent lighting systems

Grote Select® LEDs use specifically formulated encapsulated circuitry that provides protection against the elements and also incorporates a hermetic lens-to-housing seal that prevents moisture problems. They provide extremely fast light-on response times that can increase stopping alert distances. In addition, they incorporate the latest LED technology and offer much longer life than incandescent lamps and require less maintenance.

Grote Select® LEDs also have lower power requirements which make more voltage available to other systems. They make use of existing wiring pigetails for retrofit purposes and employ surface-mount electronics for cost effective reliability.
Needless to say, they fit all Grote bracket and grommet mounting applications.

Another benefit: Grote Select® LEDs are similar in appearance to incandescent lamps and are less prone to theft.

**New Markets – White Lighting**
Until recently, the only choice in work lamps was the incandescent, or Halogen lamp. These lamps worked well, but had several drawbacks such as a short bulb life of 25 to 500 hours; high amperage draw of 2.7 – 8.33 Amps; high lens temperatures, and bulbs made of glass.

**New Grote LED WhiteLight™ Work Lamps**
In 2006 Grote introduced an 18 diode LED interior lamp for trailers, the first of the new LED WhiteLight™ lamps.

2007 saw the introduction of the Grote Trilliant® work lamp. This LED work lamp now produces over 4,200 Lumens of white light. The Trilliant® was tested in the Baja 1,000 Off-Road where it went the distance without a failure. Soon thereafter the military was demanding Trilliant® LED work lamps.

The Trilliant® has interchangeable lenses. You can change a spot pattern to a flood or trapezoid pattern by just changing the outer polycarbonate lens. The Trilliant® Mini, a smaller version of the Trilliant® but with lower lumen output and fixed lenses, was introduced later.

Grote also offers the Trilliant® 36 LED bulb. This bulb will fit into any Par 36 housing replacing the 4411 incandescent bulb. It offers both screw-in and blade connection methods and is available in TractorPlus™ and wide flood light pattern.

The Trilliant® 36 LED bulb puts out 1300 lumens. It is also available in a bracketed version with a TractorPlus™ and wide flood light patterns.

The Trilliant® Cube is a smaller work light that can be placed anywhere on the vehicle where lighting is needed. Available with flood and TractorPlus™ beam patterns, the Cube makes it easy for work crews and vehicle designers to add just the right amount of light whenever and wherever it is required.

All Grote LED Trilliant® work lamps offer the following benefits:

- Active thermal management circuitry that protects the LEDs from damage
- Polycarbonate lenses
- Multiple beam patterns
- Low Amperage draw compared to filament based lamps
- Bright white light
- Easy mounting solutions
- Superior beam control and light pattern
- All LED work lamps are fully potted

Further LED WhiteLight™ product expansion, as well as increases in output and efficiency are expected in the coming years.
NOTES

ADDITIONAL RESOURCES
These resources can be acquired online or through the marketing department.