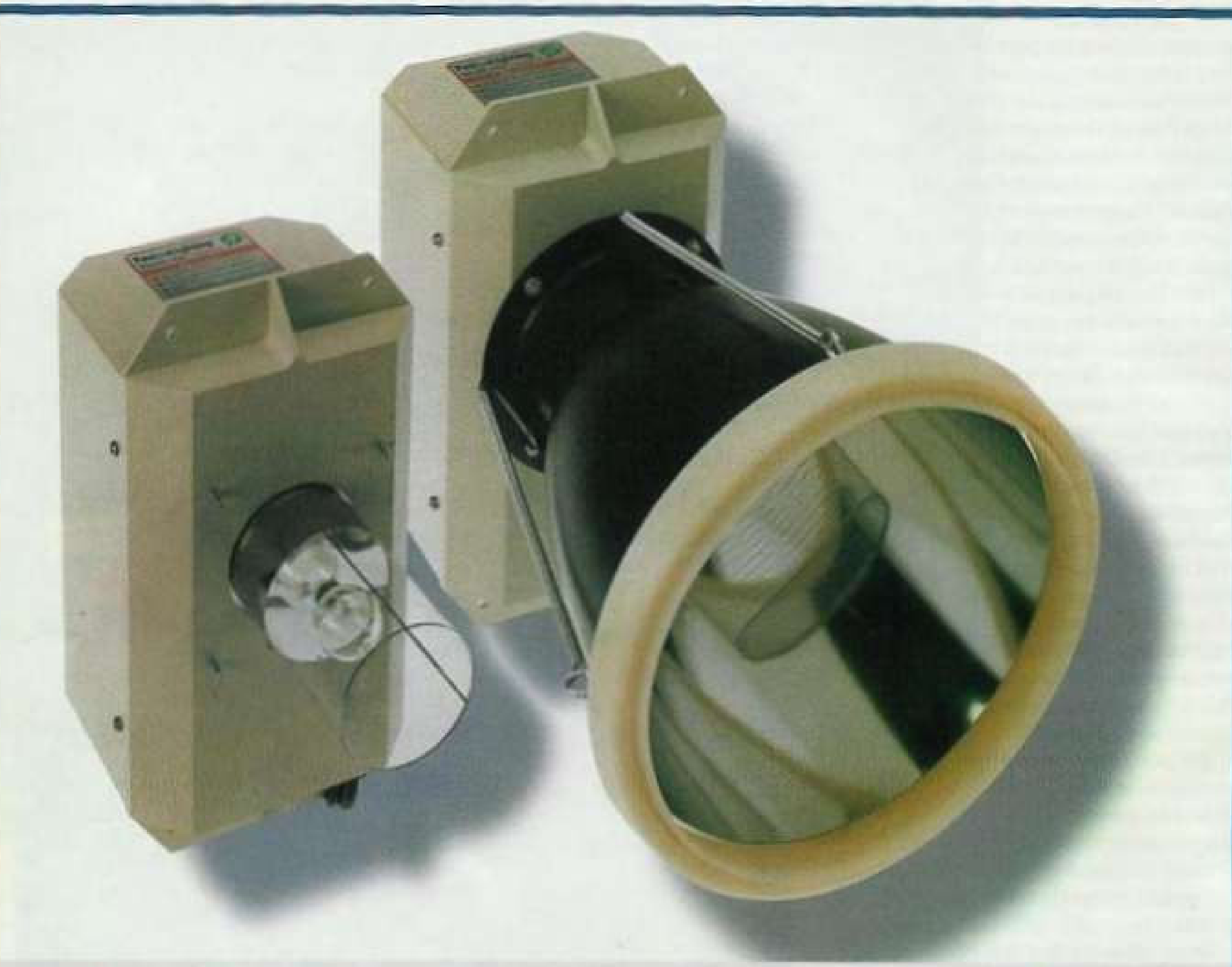


The Sulfur Lamp in Horticulture

By Trisha Coene

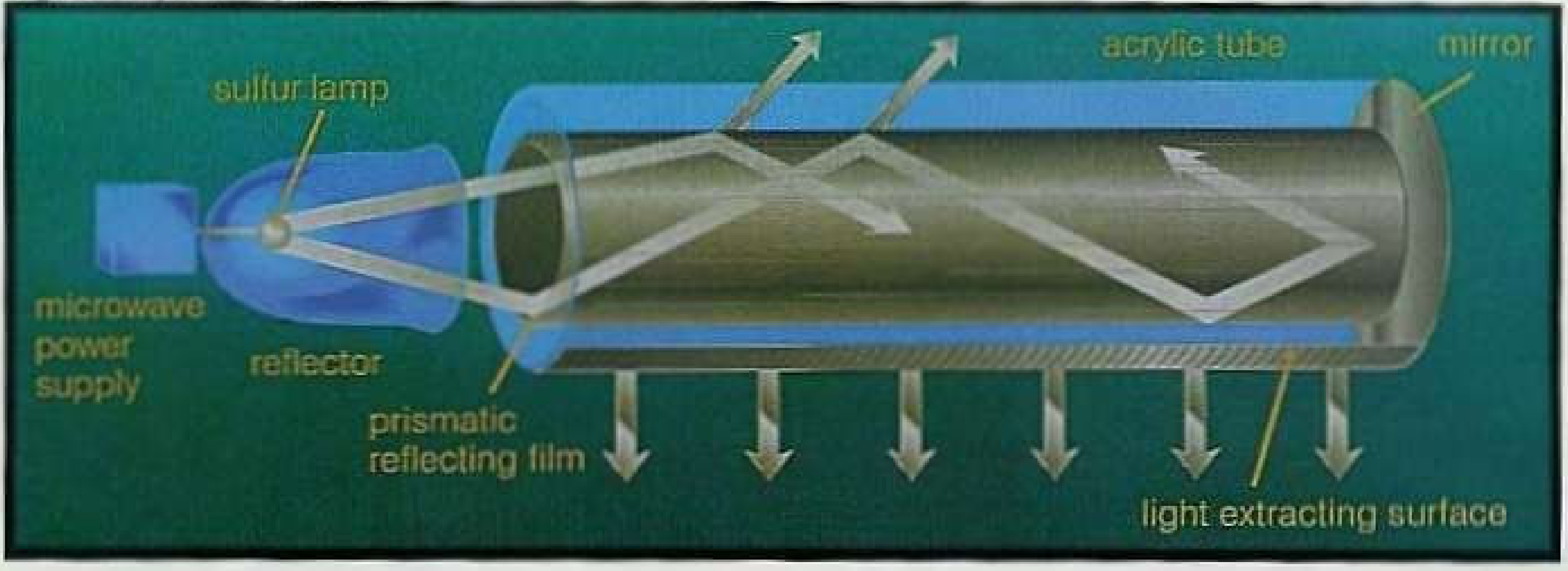
By now, most of you have probably gotten wind of the latest in high intensity discharge (HID) lighting technology, the Solar 1000™ sulfur lamp, introduced by Fusion Systems Corporation in Rockville, Maryland. About two years ago initial informa-tion on the sulfur lamp was released, ut at that time, scientists only eorized about the lamp's perfor-nce in horticultural applications; d tests hadn't yet been conducted nfirm or dispel those theories.

Now, we finally have the scoop. Over the years, the lamp has been tested in greenhouses and controlled environment growth chambers by Fusion Systems, the United States Department of Agriculture (USDA), universities throughout the world and a major seed company in Canada. Some of these tests compared the sulfur lamp to other HID lamps, while others compared it directly to the sun.

The Technology

Like all HID lamps, visible light from sulfur bulbs comes from a hot gas or plasma within a transparent envelope or bulb. In conventional lamps a current runs between special metal electrodes to heat the plasma. These electrodes seriously affect the bulb's maintenance of output and shorten its life span. That's why the plasma in the sulfur bulb is heated without electrodes. Instead, micro-wave energy interacts with the material to produce light. Basically, the sulfur bulb consists of a quartz envelope, noble gas and sulfur. To

Diagram courtesy of Fusion Systems, Inc.



Each sulfur bulb contains an inert gas and a small amount of sulfur. When the sulfur is bombarded with microwave energy, it forms a plasma that emits light very much like sunlight. The lamp can be used in a variety of different configurations. On the opening page of this article it is shown with a reflector. In the diagram above it is pictured with a light pipe. In either configuration, it can be filtered, tinted, dimmed and reflected to meet the unique lighting requirements of any facility.

this mixture, Fusion Systems has added other materials on a trial basis. However, none of these materials react with each other, which is why the sulfur bulb has such a long life and excellent output maintenance.

For those of you who missed the first article we ran on the Solar 1000 (vol. 7, no. 2, page 16), a quartz stem acts as a support in the lamp's design, holding the bulb in a specially made microwave oven. A magnetron – almost identical to those found in microwave ovens – generates the microwave energy for the sulfur bulb. The magnetron is powered by direct current electricity from a power supply that receives its energy from the alternating current electrical power mains.

The complete lamp system consists of a bulb, reflector and ballast module. Like a remote mounted ballast for a discharge lamp, the sulfur lamp's ballast module provides the necessary transformation of the line voltage to operate the electronics in the lamp. The lamp module itself contains Fusion System's patented electrodeless bulb, a magnetron, a system to couple the energy into the bulb and mechanisms to cool the internal components. Mounted on the outside of the lamp is a reflector that directs the light to the area to be illuminated.

The advantages of the sulfur lamp technology were best summarized by scientists at Fusion Systems Corporation, whose years of research and experimentation on the Solar 1000 lamp were funded by NASA SBIR (Small Business Innovation Research). The following information was excerpted from their paper entitled, "Efficient, Full-spectrum, Long-lived, Non-toxic Lamp for Plant Growth":

- Spectral Stability: Non-reactive fill materials and the absence of electrodes lead to lamps with virtually no shift in spectrum over the course of their life.
- Long Life: Life tested to nearly 10,000 hours. No evident failure mode internal to the lamp envelope has been discovered to date (infinite bulb life). System life is currently limited by magnetrons, but further development could double the system life to 20,000 hours or more.
- Fill Gas: The bulb is non-toxic, mercury-free and safe.
- Excellent Maintenance: We estimate

Allocation of Wattage over Spectrum (total power=502 watts)

Wavelength (nm)	Color	Percentage of Output
<380	ultraviolet	0.14%
380-400	near violet	0.21%
400-435	violet	1.92%
435-495	blue	18.12%
495-565	green	30.08%
565-590	yellow	9.20%
590-625	orange	10.69%
625-700	red	14.56%
700-780	near red	7.08%
>780	infrared	8.0%

that bulb light output at 10,000 hours will be 95 percent of initial output. This is referred to as "maintenance."

- Stops/Starts: Stops and starts do not affect an electrodeless bulb's lifetime.
- Rapid Start: Cold start is significantly shorter than conventional HID lamps.

MH Vs. Sulfur

In February, 1996 results from a comparison of metal halides to sulfur lamps in the growth rate and yield of corn were released from Hutchins International Limited, a major Canadian seed company based in Mississauga, Ontario.

For these tests, three separate 64-square-foot growing enclosures were created in one greenhouse. Each area was lit by either two 1000-watt metal halides or two 850-watt (designates the power in watts going to the bulb) Solar 1000 lamps. The light sources were set 4.27 feet (1.3 m) apart and 9.84 feet (3 m) from the floor. Solid vinyl curtains were used to create the enclosures and to minimize the sun's and/or other lamps' influence on the test plants, which were all identical inbred corn plants.

Despite the fact that the tests were started in late September, which is very late in the growing season, the data proved that in all circumstances the plants under the sulfur lamps significantly out-performed those under the metal halides. Results were based on kernel counts of the corn harvested from the three different growing areas. Ears with less than 100 kernels were considered failures; those with over 300 kernels were considered exceptional. Overall, it was reported that there were less failures and many more exceptional ears produced under the sulfur lamp.

From these results, the scientists made the following conclusion: a

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Solar 1000™ Specifications

The Solar 1000™ is in the late prototype stage of development. This chart, provided by Fusion Systems, reflects both data and design targets. However, as the lamp develops, some of these specifications may change.

The lumen output is the total light output of the lamp, as measured through the microwave screen. Correlated color temperature indicates the absolute temperature of an ideal Plankian radiator (blackbody source) that most closely approximates the chromaticity of the lamp. The color rendering index is a measure of the degree of color shift that objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a blackbody source of comparable color temperature. No color shift occurs when CRI = 100.

Electrical	
Input voltage and frequency	200 & 230V.50Hz. 1ø: 200 & 208V. 60Hz. 1ø
Input power	1425 W
Power factor	>.93
Physical	
Lamp module mass	6 kg
Power supply mass	22 kg
Environmental	
Ambient Operating Temperature	-20° to 60°C
Relative Humidity	90%
Output	
Total luminous flux	150,000 lumens
Correlated color temperature	6000°K
Color rendering index	≥79
Average luminance	>19 candela/mm²
Flicker (max-min)/max	≤ 15%
x chromaticity coordinate	0.3171
y chromaticity coordinate	0.397
S/P ratio	2.4
Design Lifetime	
Lamp system excluding filter and magnetron	45,000 hours
Filter, magnetron	15,000 hours

SULFUR LAMP, *continued from page 34* greenhouse using 1000-watt metal halides as supplemental lighting could expand its production of seed corn by a minimum of 23 percent to even 47 percent by changing the light sources to Solar 1000s.

Furthermore, the plants under the sulfur lamps came to seed one week earlier than those under the metal halides. According to the scientists, this has implications for crop turnover times, with the Solar 1000s again significantly improving greenhouse production efficiencies.

Sunlight Vs. Sulfur

In tests conducted at Chiba University in Matsudo, Japan, horticulturists T. Kozai, Y. Kitaya and Y.S. Oh examined the growth characteristics and grain yields of rice plants grown in a growth chamber under the sulfur lamp and compared them to plants grown under sunlight simultaneously in a greenhouse.

Obviously there were differences in the growth chamber environment as compared to that of the greenhouse, but these differences were factored into the research meticulously. In conclusion of their findings, the horticulturists wrote: "Microwave-powered lamps are useful to enhance growth of plants which require high light intensity with less electrical energy." They also reported that certain features of the lamp, including its small size, high electrical energy-to-light conversion efficiency and low emission of thermal radiation, can help plant production operations reduce electricity costs for lighting and cooling.

So far, there is no data comparing the long term energy, maintenance and potential labor savings with the use of the Solar 1000 light systems. Of course, a study of this nature should be conducted, since the sulfur lamp has already shown so many other advantages over HIDs. It could take a few years before we see results from such a comparison, but estimates on these cost savings are very promising. ❖

Trisha Coene is the editor of The Growing EDGE. *This is her last issue [so long, everybody ☺].*