UV FOR CONTRACTORS

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Abstract
New and improved UV coatings for wood, concrete, anti-graffiti, marble and granite countertops appearing in the marketplace, have generated a variety of new portable UV curing equipment. This has produced a new generation of entrepreneurs, contractors, and businessmen exploring UV technology for its benefits, practicality, and profitability.

Often, UV technology is introduced to the novice at a trade show with a demonstration showing a wet coating being applied to a piece of wood, plastic, or stone and instantly cured after a bright light is swept over the coating. Typical reactions are "shock and awe," followed by many questions. The intent of this paper is to present a better understanding of UV curing for contractors including coating and equipment choices, coating techniques, safety, and tips for successful UV applications.

Advantages of UV Coatings

The many advantages of UV coatings for the contractor include: instant cure, rapid application, fast small-section rework, no evaporation (solvent smell), instant bond test and recoat capabilities, etc.

UV Curing

Ultraviolet or UV curing occurs when specific liquids are instantly solidified by the exposure to certain UV lights. The process can be better understood by the concepts illustrated in the following examples.

How UV Curing Works

Water exists in three states: gas, liquid, and solid. The only difference, between these states, is how many H_2O molecules are bound together. Water vapor exists as a single molecule; liquid (water) exists, as a combination of three to four molecules, and ice is many molecules "glued" together. *The more molecules bound together, the thicker or more viscous the liquid becomes.*

Crude oil exists as a long chain of carbon atoms (60-80) bound together. As it's heated (distilled), these long chains break apart into shorter molecules producing many compounds including kerosene (15 atoms), gasoline (six atoms), butane (four atoms), propane (three atoms) and finally methane (one atom*). The shorter the molecular chain, the less viscous the liquid becomes.*

If the opposite process is done, such as "gluing" a few oil molecules together, the result is wax (100 atoms), and if thousands of oil molecules are glued together, polyethylene is created. UV liquids are similar: the energy in UV light activates the short molecules to bond together into very long molecular chains or solids. This is why nothing evaporates when UV coatings cure.

Whether for environmental reasons, or the rapid cure features, the contractor's motivation is critical for success. UV technology may or may not work the first time and there is no guarantee it will work on every surface. However, to achieve the highest success in the shortest time, three things are required: a well-formulated UV coating, a practical and consistent UV light, and a good understanding of UV curing procedures.

Selecting The Best UV Coating

UV coatings are the combination of man-made materials (monomers and oligomers) combined to achieve a certain result. A special light absorber (photoinitiator) is added (1-5%) to make them cure with UV light by producing active molecules (free radicals), which initiate the polymerization process. Advanced coatings now offer built-in photoinitiators, can be thinned with water, show no surface tackiness at low UV intensity, and cure on curved surfaces.

UV coatings formulated by the manufacturer should accomplish five basic missions:

- Ease of application
- Adhesion (to specific surfaces)
- Specific properties
- UV curable (at acceptable speeds)
- Safety

Currently there is no universal coating that can be used on all surfaces/substrates. A variety of chemistry is used to achieve the proper adhesion and thickness. Shrinkage may cause separation from the surface if the coating is applied too thick, and materials like metal, glass, and plastics, are hard to stick to and require special attention.

Wood usually requires two coatings to achieve a smooth finish. The first coat generally raises the grain and therefore requires a light sanding to make the surface smooth, and to help the second coat stick. Oily woods are more challenging, but proprietary coatings have been successful even for this difficult application.

Coating properties

The formulator controls the gloss, adhesion, chemical, scratch and abrasion resistance, and non-yellowing properties. In general:

- Matte or satin coatings may contain solid particles and therefore must be well mixed (without entrapping air bubbles in the coating).
- Water and solvent borne UV coatings are low in viscosity and therefore easier to spread, however the coating should dry for minutes to hours, as required, before curing with UV.
- UV acrylate urethane floor coatings (widely used) are widely used in commercial, residential and specialty applications.
- Acetone can be used as a thinner for coatings that don't flow-out well, however it must evaporate before the coating can be cured and the quality may be inferior.

Coating Outdoors
To ensure the coating is not cured from the sun's UV rays, tent 12' x 12' sections and cure with UV lamp (repeat process until area is completely cured). If the coating is exposed to sunshine, a tacky surface and poor quality may result. However, tenting may not be necessary if a coating is formulated for a sun cure.

Coating Indoors
While tenting is not necessary indoors, it is important to note that fluorescent lamps may partially cure the surface if left exposed for several hours. Some application tips and methods include:

- Foam rollers: Used for low viscosity coatings
- Squeegee or Chamois: Used for viscous coatings to achieve a thin application
- Lint Free Cloths/Paper Wipes: Used when applying a gloss or semi-gloss coating (reflected light makes any small imperfection visible)
- Spraying: Used with low viscosity coatings (breathing mask required)
- Cold Weather: Work in smaller areas where the temperature can be controlled, because UV coatings do not flow well in cold temperatures and change in appearance.

Floor Application Tips
It's important that workers have some training in floor coating before beginning the UV process. UV coatings can be rolled, brushed or sprayed, however the most common application is with a roller. Use a low knap, lint free pad of a non-fibrous material, because UV coating are very sensitive to foreign substances. (Ensure the uncured surface is not exposed to dust).

Floor Prep: Do this exactly as with any other standard coating, I.e.: epoxy, urethane, etc. The only difference is once the floor is considered spotless wash it one more time because even one speck of dust will show up with glossy UV coatings.

Coating Roll Out: Just as with standard coatings, start from one corner of the room and work from one side of the room to the other until the floor is evenly coated.

Lamp Usage: When approximately 75 percent of the room is coated, and has achieved a flattened appearance, begin the curing process by turning on the UV floor lamp. (If only one person is coating and curing, the entire floor must be coated before curing begins).

Curing Process: Begin by curing a 15" wide path (with a 15" lamp) along the starting wall. Push the floor machine onward over the freshly cured coating**. Remember UV coatings cure instantly, meaning the cured surface can be walked on immediately after the lamp passes over it.** A short strip of wet material will be left along the wall because the light shield for the lamp is 21" wide while the bulb length is only 15".

- Keep your feet and the cord out of the wet material.
- After the first pass with the machine, there will not be enough room to turn the machine around. Since UV coatings cannot be over-cured, simply back up

and continue curing the next 15” path. (Note: The coating can burn it if the machine is left on and idle).

- From the starting location move over the previous path by one-inch continue until the end and then reverse direction.
- Because wet coating looks the same (glossy coatings) as when it is dry, locate the edge of the cured material.
- Continue this process until finished.
- Finish the edges where the UV light didn’t reach.
- Position the floor machine facing the wall from about one-foot away. Tilt the machine back slightly to ensure the coating is cured right up to the wall. Move sideways curing the next 15” section of wall repeat the process until the uncured strip is cured.
- When these steps are complete the floor is immediately ready for use.

UV Curing Tips

The 1,046 square foot house in Figure 1 requires four coatings: wood, concrete, tile, and linoleum. All floors may require a light sanding to prepare the surface for adhesion. First apply the coating to a small region of each floor and cure to test for appearance and adhesion. This is a very important step and can save hours of work if any of the coatings are not compatible with the existing floor substrate.

Next check the location of the electrical outlets. The floor machine requires 220-volts and heavy-duty extension cords to reach all curing areas. It is important to have extra 220-volt male plugs since older homes may have different 220-volt receptacles. (Portable, hand-held units typically work on any 110-volt outlet).

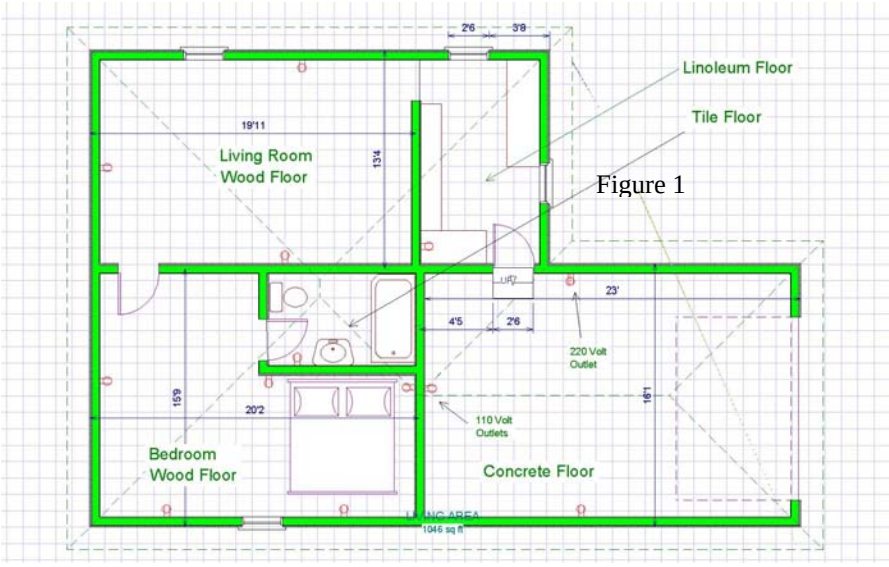

Figure 1

After the coating samples have passed inspection, proceed with the room farthest from the front door, the bedroom in this example. If furniture is in the rooms move to one side and coat and cure these areas first. Move the furniture onto the cured area remembering not to step on the one-foot strip of intentionally uncured coating. This will help blend the first and second coatings.

Smaller rooms such as the bathroom and kitchen need to be cured with a portable hand-held unit. In the living room, curing will start from the kitchen door, as described in Figure 2.

The garage should be coated and cured last and may have to be coated and cured in two steps. The far end is coated and cured first with the garage door closed, and then the second half is coated and cured. Remember not to step on the one-foot uncured strip left in between the coating areas.

Most coatings do not adhere well to wet or humid concrete. This is especially true in low-lying areas or below water-line levels. In such situations, hydrostatic pressure from groundwater, or moisture eventually overstresses the coating and causes adhesion failure. Concrete slabs should be tested for moisture regardless of age or grade level. It is highly recommended, that the industry standard, *ASTM F 710 Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring,* be followed, before UV coatings are applied to concrete. At a minimum, an electronic moisture meter should be used to measure the moisture content of the slab. In addition, an alkalinity test should also be performed. A high reading (nine and above) usually indicates moisture vapor is moving up through the slab and is alkaline in nature, which is deleterious to most adhesives. In such cases, a proven sealer must be used to eliminate the moisture, before any coating is applied.

Coating Application Methodology

Figure 2 shows a typical room with one door. After the floor is prepared and coated, start curing region 1 from the door to the back wall. Double back on the cured portion until you are outside the room, move the floor machine to the other side of the door and cure a path as wide as the door to the back wall.

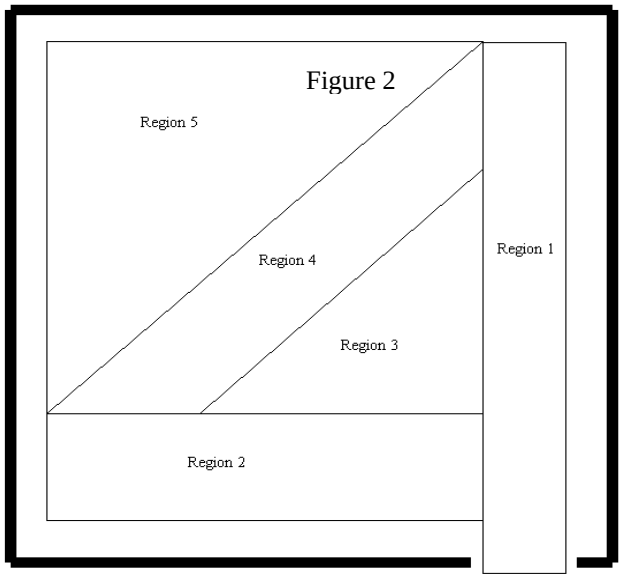

Figure 2

Proceed in a similar manner to cure region 2. Then with a back and forth motion, proceed to regions 3, 4, and 5 as illustrated. The strip near the wall can be cured with a hand-held unit, or with the UV floor machine in a back-forth movement along the wall (tilt the machine slightly to direct the light at the wall).

Room-to Room (or stalled process)

If a room is left unfinished (or the process stopped) leave at least a one-foot strip of wet material along the edge to create an overlap line. This will ensure a smooth transition when the process is resumed.

Remember, wet material will stay wet indefinitely if it is not exposed to light (UV or fluorescent lights). Therefore a wet strip can remain as is until light is introduced. If the process is interrupted, place a barrier to ensure that no one steps on the uncured coating (wet coating looks the same as when it is dry). If the uncured coating is stepped on, it can be recoated before being exposed to UV light.

The Best UV Light

UV lamps are similar to florescent lamps but typically smaller in diameter and much more powerful. They are rated in watts per inch and are available from 100 to more than 1,000 watts per inch. For the contractor, a lamp with several hundred watts per inch is recommended. Typically, at least two lamp sizes are necessary, at least 15-inches for large areas (living room, bedroom) and eight inches for smaller areas (bathroom, laundry room). A residential 115-volt outlet can handle about 1800 watts, which can easily power an 8-inch lamp that's rated at 200 watts per inch.

The lamp is housed in a casing with a reflector that focuses the light from one to several inches from the housing. This line focus is where the maximum intensity occurs. The lamp must be kept at that distance from the coating for proper (fastest) curing. For some coatings, however, running slightly out of focus (more distance from the floor) is recommended, to eliminate cure lines, at the edge of the focus line.

Because the lamp can reach more than 1000 degrees Fahrenheit during operation, cooling is supplied to the lamp-housing assembly. For portability, the lamp should have a handle, and is normally connected to a power supply through an umbilical cable, which can be up to 50 feet in length.

Three key issues are important when selecting a UV lamp system:

- Ease of use
- Repeatability
- Safety

The UV curing industry is nearly four decades old and has evolved standard, rugged and reliable UV lamp systems used for a variety of commercial processes including curing printing inks and processing products on a conveyor including wood, linoleum, floor tiles, car parts, etc. Today, portable UV spot curing equipment, for curing dime-sized areas on small parts, is also available, but portable UV curing equipment, (3-15 inches wide), is new to the industry, and has yet to evolve into standardized systems.

UV floor curing equipment can range from large gasoline generator driven systems to small portable hand held UV lamps, which are used on walls, corners, and countertops. The key issue with UV coatings applied to existing facilities, is ease of navigation of the curing equipment, in small spaces, corners, and near walls. Ease of use of the UV lamp depends on its portability (size and weight), ease of changing the lamp, length and flexibility of the umbilical cord, and lamp operation (lamp On-Off characteristics).

The lamp restart time, once it is turned off, depends on the power supply. Since the operator must wear (dark) protective glasses, the lamp is often turned on and off to

inspect the progress of the job. In tight areas, this may occur several times per minute; therefore it is both safer and more efficient to have an instant On-Off UV curing system.

Currently, there are four types of four power supply types for UV lamps:

Power Supply Type	Advantages	Disadvantages
Magnetic Ballast	Low Cost, Reliable	Heavy, Lengthy Restart Time
Electronic Ballast	Lightweight	Lengthy Restart Time
Microwave	Instant On-Off, Long Life	Bulky, Limited Lamp Size
Min-eLux™	Instant On-Off	Limited Lamp Size

The UV lamp has liquid mercury inside which must evaporate into a gas for maximum UV output. This process usually takes 3 to 5 minutes. When the lamp is switched off, it must cool down to room temperature for the mercury to condense, and re-ignite by the power supply. This may take another 3 to 5 minutes, and therefore, the lamp may take up to 10 minutes to reach full power again. This is inefficient for the contractor.

Magnetic Ballast: Basic transformer and capacitor power sources have been available for decades. They are very reliable, but also very heavy. Theses power supplies are used most often in high power applications if a lamp is more than 20 inches long. The main disadvantage is they are heavy and take a long time to restart.

Electronic Ballast: Systems under 3 kW are lightweight and can power up to a 15-inch lamp. The disadvantage is the long restart times.

Microwave Power Supplies: Reliable with instant On-Off capabilities, but are bulky and only available up to 10 inches wide. They are not portable, but may be used in large motorized systems.

Min-eLux ™ Equipment: Patent-pending UV technology that offers maximum portability, ease of use, increased efficiency, and instant On-Off capability. Currently three portable systems are available: 3" **UVwand**, the 8" **UVsabre**, and the FX-1U floor machine with 15" **UVsword**.

3" **UVwand** (1200 W)

8" **UVsabre** (1600 W)

Carrying case for **UVwand** and **UVsabre**

Portable Upright model: FX-1U with 15" **UVsword** (3500 W)

A real-time power meter, which measures the lamp's output power, is highly recommended for all lamps.

The Cost of UV Coatings and Equipment

UV coatings today can cost from $60 to $300 per gallon. One gallon covers about 1,500 square feet for a one-mil thick (1/1000 inch) application. Since there is no evaporation, UV coatings can be competitive with conventional high quality solvent-based coatings with similar performance.

Portable UV equipment can be purchased for under $10,000. Medium-sized floor units range from $9,500-$19,500. Larger motorized systems range from $20,000-$50,000.

Safety with UV Equipment

UV curing safety is of primary importance. Proper handling of chemicals and UV lamps should be followed at all times—before beginning a job thoroughly review the MSDS manual. Some important safety guidelines to follow include:

- Always wear protective UV eyeglasses when operating a UV lamp.
- Test your glasses with a calibrated UV sensor.
- Never look directly at the lamp, even with UV safety glasses.
- Never point lamp at any shiny aluminum, it reflects almost 90 percent of UV radiation. (Other metals are less reflective).
- Protect your skin and face during extended exposure (sunscreen with 30 or more SPF).
- Wear protective gloves when handling coatings.
- Open coating containers in well-ventilated rooms.
- Wear a mask when spraying UV coatings.
- Wash your hands immediately if any skin contact is made with the coating
- If you experience any skin irritation immediately contact the manufacturer (Request that the reactive monomer be replaced with a less toxic compound).
- Refrain from using any coating if you notice any skin irritation (Skin irritation does not imply toxicity, some individuals are more sensitive than others).
- Ozone is generated when the lamp first warms up. Operate in a well-ventilated room and wear breathing mask. Ozone-free lamps minimize these fumes.

For comparison purposes, the following readings were measured with a UV-A meter:

Source	Distance/Position	UV-A Intensity (watts/m^2)
Winter Sun	34º North Latitude 800 w/m^2 visible	20.0
UVwand (1200 watts)	1 inch (lamp focus)	15,000.00
	3 inches from lamp	300.00
	24 inches from lamp	50.00
	Reflected by 6"x 6" aluminum plate (2 feet away)	1.00

	Reflected by 6” x 6” steel plate (2 feet away)	0.50
	Reflected by white wall (10 feet away)	0.10

The table illustrates how quickly lamp intensity drops when curing out of focus. It also shows how dangerous the UV lamp is compared to the sun. UV exposure from the lamp at one-inch away is nearly 15 times as intense as sunlight; therefore never operate UV systems without eye and skin protection. Instant darkening UV glasses are now available and indispensable when curing UV coatings.

Troubleshooting

Coating and Curing Problems

Remember, there is not one all-purpose UV coating, each coating is formulated for adhesion to a specific surface. Be sure to work with the coating manufacturer to select the right UV coating for your specific application.

The following problems may arise even with a well-formulated coating:

- Lack of adhesion
- Cracking
- Softness
- Tacky surface

Lamp problems include:

- Lamp intensity is inadequate for your specific coating (causing a tacky surface)
- Lamp focal point is out of focus (too far away)
- Lamp was moved too quickly over area
- Incorrect lamp is used, or lamp is old

Mercury lamps generally degrade over time exhibiting approximately a 10-40 percent drop in power after 1000 hours of operation. In addition, over time or rough handling, some lamps may lose a substantial part of their UV output, while others may not degrade substantially. Therefore it is important to always measure the lamp’s UV output with a UV-A detector before each job and have several spare lamps on hand.

Oxygen Inhibition

If the coating surface still appears tacky, the problem may be with the lamp. Oxygen can prevent curing at the surface by deactivating free radicals. Ensure the lamp is at the right intensity (specified by the formulator) using a UV-A meter to measure the output. Anything below this specified minimum level may cause a surface to be either tacky or soft. The formulator may solve this and other issues such as poor adhesion, scratch resistance, or a noticeable odor.

UV Coatings Issues

UV coatings are a new frontier for contractors. However, as with anything new, practice makes perfect. Once this is achieved, the use of UV coatings will enhance productivity,

reduce costs and help improve the overall environment. From experience, following these few simple rules can help achieve success with UV coatings and equipment.

Rule #1: Work with a distributor that manufactures the coating, can change or improve the coating, and also distributes and services the UV equipment.
Ensure the manufacturer can change or improve coatings and tests them with your UV or similar equipment. This avoids many problems.

Rule #2: Perform an Actual Test Before Beginning the Job
Don't assume the results in a lab environment will be the same as on a jobsite surface

- Remember the surface at the jobsite may be greasy, or have a previous coating, or has absorbed fumes from years of exposure to the elements.
- Even after intense grinding, cleaning, or acid etching, the coating may still not stick; be prepared.

Rule #3: Practice, Practice, And Practice
UV coatings can and should be continually improved to reach the desired appearance and performance for the customer. You are responsible to make it work.

GLOSSARY

Definitions:
Monomers: The basic element or molecule, which when linked with similar molecules, forms a polymer.

Oligomer: A polymer that consists of a two or more monomers.

Polymers: Any of numerous natural or synthetic compounds of high molecular weight consisting of repeated linked units, each a relatively light and simple molecule.

Polymerization: 1) The bonding of two or more monomers and oligomers to form a long molecules called polymers.

Ultraviolet**:** Invisible radiation wavelengths from about 10-400 nanometers (10^{-9} meters). UV-A is 400-315 nanometers (nm), UV-B is 315-280 nm, and UV-C is 280-10 nm.

Molecule: A combination of atoms bonded together.

Polyethylene: A polymerized ethylene resin (plastic), used especially for containers, kitchenware, and tubing in the form of films and sheets for packaging.

Substrate: A wood, concrete, plastic, or glass surface.

Acrylate: Any of a class of acrylic resins used especially in emulsion paints, adhesives and plastic.

Free Radical: An excited atom or molecule which starts the polymerization process.

Cationic Cure: Initiates the curing process with negative ions, once initiated, polymerization may proceed without exposure to radiation. This is useful for pigmented or curing curved surfaces. This type of polymerization does not exhibit oxygen inhibition.

Ballast: A magnetic transformer, which limits the current through it.

Min-eLux™ : A registered Trademark of Adastra Technologies, including the **UVwand**, **UVsabre**, and **UVsword** portable UV curing systems.

Energy Calculation: If a coating requires 0.25 joules per cm^2 to cure, and you measure 1.5 watts/cm^2 of UV-A from your lamp, how fast can you cure if your focus is 1 cm wide?

Answer. 1 watt is one joule per second, so at 1.5 watts we can achieve cure at 1/6 (1.5/0.25) second, or a speed of 6 cm per second, or 12 feet per minute. Some UV coatings can be cured even at hundreds of feet per minute.

Pencil Test: Coating is cured on a substrate and marked with a 100-micron diameter sharp pencil from 1H to 8H.

Ozone: Generated by UV-C radiation, usually when a mercury lamp is first turned on. Ozone free lamps eliminate ozone production.

References

Radiation Curing of Coatings, Joseph V. Koleske, ASTM International, 2002
UV/EB Curing Technology & Equipment, R. Mehnert, A. Pincus, I. Janorsky, R. Stowe & A. Berejka, Volume 1, Wiley & Sons, 1998

Suggested Reading

Polymer Materials; An Introduction for Technologists and Scientists, Christopher Hall, John Wiley & Sons, 1989

Bios

George Wakalopulos has founded three high tech companies, holds more than 30 patents, has published numerous scientific papers, and received several awards related to lasers, holography, electron beams, and UV equipment. Major accomplishments include the development of the world's most rugged electron gun, the WIP EB system, used by the military for airborne high power "star wars" lasers, and recently, the Min-EB, the world's smallest, least expensive, and lowest voltage electron beam vacuum tube, now used in a variety of industries including, sterilization, polymerization, cross-linking, and analytic chemistry.

He is currently the founder of Adastra Technologies Inc., which has developed small and portable UV curing equipment (Min-eLux)™, novel real- time UV sensors, and related floor coating equipment. Mr. Wakalopulos holds a B.S. degree in Systems Engineering from UCLA and a M.S. degree in Quantum Electronics from USC.

Christy Dennis is a former television news reporter with more than 15 years experience—including an investigative report that uncovered groundwater pollution by a Fortune 100 company which led to a $333 million settlement and a major motion picture: Erin Brokovich. With a passion for the environment, she became the first marketing director for non-profit land trust organization, which gained national recognition. Combining skills of journalism and marketing Ms. Dennis joined a Fortune 100 company (Pacific Gas and Electric Company) to be a spokesperson at its company headquarters in San Francisco. She then became a manager within a newly formed department created to focus on customer communication issues. A graduate of California State University, Fresno (B.A. Journalism), she now has a consulting business: Media Solutions Associates.