Optimizing the Curing Process

Improving curing oven efficiency using product-based temperature monitoring...

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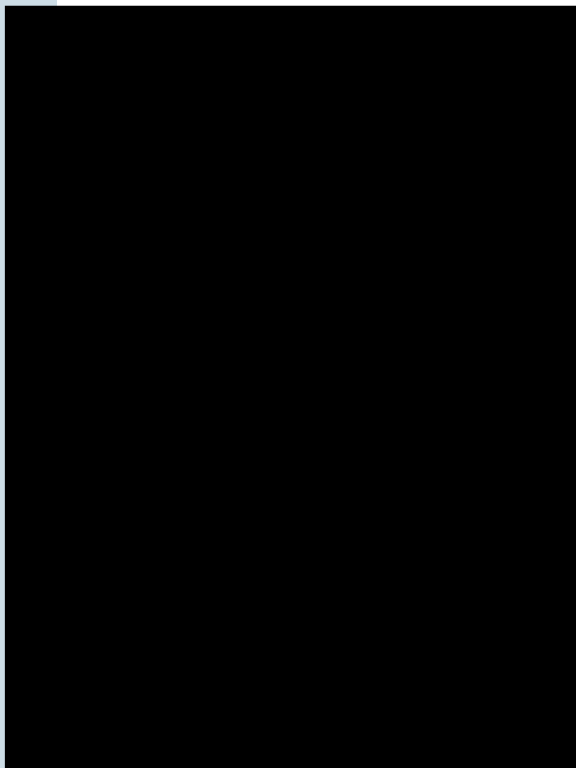
Only two controls on any finishing line are easily adjusted to regulate curing conditions. These are the conveyor track speed and the oven temperature. If these are poorly adjusted, undercuring, overcuring, low production, high fuel costs, rework and high reject rates can result.

PROBES are attached to different areas of the part, allowing for precise tracking of oven temperature.



Before deciding what needs to be adjusted, it is necessary to know what is happening inside the oven. This is not easy in a conveyorized process. One way is to obtain a profile of the variation in product temperature as the product travels through the oven. The information can be used to assess cure efficiency. If the profile reveals problems in an oven, they can be corrected.

The effect of these changes can be monitored and ultimately this process will yield measurable improvements in plant efficiency and thus productivity. Monitoring temperature on a regular basis makes it easier to discover and predict process faults before they have serious impact.

Practical Implications. Paint finish quality and the cost involved in finishing are directly related to process control. So what can be done to improve control and efficiency?

Time to Reach Temperature. All products have thermal mass and take a finite time to reach curing temperature. The greater the mass, the longer it takes to warm up. However, in getting to temperature, some curing takes place. A paint manufacturer's cure specification consists of constant temperature and time information. A greater or smaller allowance must be made for this, and it is often a guess.

Dwell Time. In an ideal world, all parts of the workpiece would reach the manufacturer's recommended curing temperature instantly and return immediately to ambient temperature after curing. However, even in this "ideal" case, there are differing thermal masses on the same workpiece and temperature variations through the oven.

Over-cure and Under-cure. On a part made from two different gauges of metal, the thinner gauge material heats up more quickly than the thicker gauge. It is possible to overcure the coating on the thin gauge part because it spends a longer time at temperature, while attempting to give the thicker part sufficient time for complete cure.

The effect of this can be coating degradation or discoloration on the thin-gauge material. At the other end of the scale, the thin-gauge material could receive an optimum cure while the coating on the thick material remains undercured. It is not possible to achieve the best cure regime without knowing detailed product temperature information.

Temperature Gradient in Oven. If products are suspended from a conveyor hanger, a product hanging lower is likely to experience a lower air temperature than a product suspended closer to the overhead conveyor. This effect can be reduced if the air blowing system creates good turbulence and circulation. However, the question remains: "What is the temperature difference between top and bottom?" This temperature differential translates directly into a set of different cure regimes from top to bottom. Similar ef-

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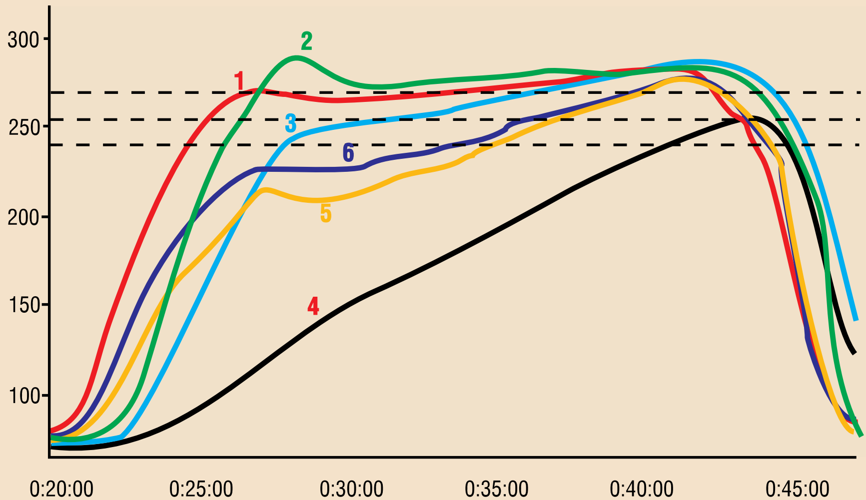
Oven: Ecaot 3	Report Date: july 1, 1995
Product: A Body	Line Speed: 45 CPH

Temperature (F) against Time (hrs)



Probes	Value Threshold Calculations						Peak	
Temp	Min:235	Low:240	Mid:255	Hi:270	Max:280	Value	Temp	Time
Time		0:40:00	0:25:00	0:15:00				reached
1. Hood center	0:19:40	0:19:15	0:18:10	0:10:00	0:03:30	138	284	0:40:15
2. Trunk base	0:20:10	0:19:50	0:18:40	0:17:20	0:11:15	183	289	0:28:10
3. Rear door skin	0:18:20	0:18:00	0:13:55	0:08:40	0:05:20	127	289	0:42:25
4. A Pillar RHS	0:06:00	0:05:20	0:03:00	0:00:00	0:00:00	22	261	0:43:30
5. Rocker Panel	0:10:30	0:09:30	0:06:55	0:03:35	0:00:25	57	280	0:41:55
6. Rear Wing	0:12:50	0:10:45	0:07:50	0:03:15	0:00:00	62	275	0:40:30

STANDARD oven temperature tracking report

fects can be traced to left/right temperature uniformity problems.

Oven Hot and Cold Spots. All convection ovens operate on an air-circulation principle. Air blowing into the oven is hotter than air being pulled out of the oven. As the product passes through the oven on the conveyor, it will pass through hot and cold zones, depending on the oven design.

However, the oven temperature controller generally reads temperature from just one thermocouple input. This thermocouple can only read temperature at one point. Depending on its position, the thermocouple detects a temperature that is different from the air temperature surrounding the product in another part of the oven.

Run Information
Name: ECOAT
Operator: DAF
Cycle Time: 25 min.
Transducer Id.: A611-258-00
Number of Probes: 6
Sampling Interval: 0:00:05
Trigger Mode: None
Data Loaded: 10:34:00 on 09/05/88

Comments
You can enter up to 8 lines of information in this space. i.e.,
Coating type, zone settings, comments on runs, etc.

Max temp. 280 (F) exceeded by probe(s) 1, 2, 3, 5

Faulty Oven Hardware. Failure in any part of the oven diminishes curing process efficiency. Common occurrences such as faulty heater elements and circulation fans, open doors and incorrectly adjusted vents all affect the air temperature and circulation within the oven. Any one of these can change the oven cure cycle.

A 20 deg difference in average air temperature can halve coating cure rate. To obtain the same cure, the product has to be heated twice as long. This could mean a 50 pct reduction in production if the problem is noticed, or a 50 pct undercured product if it is not.

Conveyor Track Speeds. A dial reading on the speed controller does not necessarily indicate that the track is running at the same speed as the last time that setting was used. The dwell time in the oven can easily be measured on a regular basis, but this tends to be overlooked as operators become familiar with the oven equipment. The only time speed changes are apparent is when product quality deteriorates sufficiently for it to be noticed. By this stage, a large quantity of poorly finished product may have been produced.

The Solution. There are many options open to finishers. Hammer tests and paint-peel tests show whether the coating conforms to the required standard. Thermal contact strips indicate peak metal temperature. However, if there is a quality problem, such tests cannot indicate the root cause of the failure.

The best method of achieving an accurate picture of the process is to monitor the temperature of the product as it passes through the oven. With modern electronics and computer power this is possible.

The Tools. To understand what is happening in the process, it is useful to list the things one should look for.

- Is the air at the required temperature?

• Does the product reach the required temperature?
• Is there a temperature variation across the product?
• Is there a temperature variation in the oven?
• Is the product at temperature for long enough?

From this list one can specify what is necessary to monitor the process. One needs a way to measure air temperature at the product as well as a way to measure product temperature. Measuring the temperature at more than one point will assess temperature variability across the product. The more measuring points that are included, the less chance there is of obtaining ambiguous information.

Once the information is collected, it should be stored and displayed in a way that makes it easy to interpret. There should be a means to evaluate the continuously changing temperature/time information and provide a single number index of cure.

The hardware required to collect temperature data accurately and conveniently consists first of a type-K thermocouple. There are many advantages of using type-K thermocouples. They can easily be built into rugged temperature probes and are cost effective, relative to other thermocouple materials and other temperature-measuring devices.

Temperature readings from each thermocouple should be stored throughout the process. This requires an electronic data logger. If the data logger passes through the oven with the product, production will not be disturbed. This also ensures that the cost of thermocouple wire is minimized because only relatively short wire is required. Shorter wires also ensure more accurate readings and are easy to handle.

The data logger has to be kept cool to survive the oven temperature and ensure that electronic measuring circuits remain accurate. Placing the logger in a rugged thermal barrier satisfies both of these requirements.

After the process, the digitized temperature data can be analyzed using a PC. It is here that the data are turned into usable information. A color plotter plots a graph of temperature against time for each thermocouple probe. Plotting all the profiles together shows how product temperature changes as a consequence of factors discussed previously. Color profiles make it easier to identify which curve relates to which position on the product.

Know the Process. The time taken for products to reach and dwell at temperature is instantly available to the operator. He can now tune the temperature and line speed controls to ensure that correct cure is achieved. If the workpiece is overcured, the temperature can be reduced or the line speed increased, thereby reducing overcure and improving finish quality. The secondary but very valuable effect of this could be reduced fuel costs or increased production rate.

Identify Problems. By inspecting the process temperature graph, any problem areas can be identified. Hot and cold spots in the oven are easier to see on a compressed graph than on a two-ft length of chart recorder paper. Sudden drops in temperature can usually be matched to open doors or holes in the oven wall. Hot spots could point to missing baffles, incorrectly placed air ducts or shadowing effects caused by direction of air circulation.

Automatic Process Control Documentation. The advantages of using a PC are apparent at this stage. Specific software makes it possible to produce a printout of the process summary report quickly. This gives the operator all the information required to ensure that the correct cure has been achieved. Calculations are fast and produced automatically, ensuring credible results.

Rapid Process Set-up. For those involved with setting up new paint finishing processes, the trial and error approach can be discarded. This means less waste, less time spent setting up the process and full-scale production can begin earlier. The cost implications of these factors can be considerable for everyone, especially for large plants or for those coating a wide variety of products.

Reduce Rejects. When carried out on a regular basis, product-based temperature monitoring can raise process control to new heights. Comparing the temperature profiles of one production batch with the next reveals even small changes that may impact on color matching, for example. Problems can be predicted before they affect production and quality levels.

Quality finishes require tight process control. Computerized temperature monitoring systems are now an accepted tool for quality control in today's finishing industry.

Documented benefits of use include optimally cured coatings; overcure and undercure reduction; correct oven balance; understanding factors affecting the cure quality; energy cost reduction; and progress towards IS0 9000 or other SPC programs through process temperature documentation.

The net effect of these factors is to reduce costs and improve yield by ensuring optimal quality and productivity. Cure evaluation by product-based temperature monitoring is the most effective way to ensure the necessary tight process control. It is a vital part of the finisher's armory against the stiffer competitive challenges that face us in the 90's. **PF**

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