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APPLIED Co$t MODELING

Information Exchange For Your Application & Use Of Cost Modeling

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March 2001

In Situ Endpoint Control Saves Chemicals in Wet Processing

by David Taraci, Jerry Weston, SEZ America
Fred Wertsching, Luxtron Corporation

Overview

Investigation of endpoint detection, using cost of ownership analysis, on a pre-lithography backside film-removal step helped to determine how the capital investment of an endpoint detection system affects the cost/good wafer equivalent. Results showed a 12.5% increase in throughput and 14% savings in process chemicals and consumables. These factors led to an overall reduction in the cost/good wafer equivalent of 10.4% — from \$3.46/wafer to \$3.10/wafer. The value of adding endpoint control is realized further when increased utilization requires additional tools.

In situ process control, such as endpoint detection, is a key to success in maximizing yields on 180nm technology and beyond. However, this increase in control typically requires an increase in capital investment, thus affecting per-wafer-manufacturing costs. For this reason, implementation of in situ process monitoring for many process steps that do not require such strict control is often overlooked. It is possible to benefit from in situ process control while still reducing the overall cost/wafer. In particular, we have used cost of ownership (COO) analysis to look at the benefits of endpoint detection on a pre-photolithography backside film removal step and its effect — measured as the cost/good wafer equivalent (GWE) — on capital investment, chemical consumption, throughput, and other factors.

Continued on page 3

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2001 Calendar of Events

July

13-14 SEMI-sponsored seminar
"How to Successfully Manage New Product Introductions"
Moscone Hall
San Francisco, California

16-20 SEMICON West 2001
San Francisco/San Jose, California

16-18 Visit WWK's Booth at SEMICON West
Moscone Hall North • Booth 6574
San Francisco, California

17 SEMI-sponsored seminar
"Understanding and Using Cost of Ownership for Wafer Fab"
Moscone Hall
San Francisco, California

19 SEMI-sponsored seminar
"Understanding and Using Cost of Ownership for Assembly & Packaging"
Fairmont Hotel
San Jose, California

Doing the tests

In our tests, we gathered process data from a SEZ Spin-Processor 203 for film removal equipped with a Luxtron 1015 [1] for in situ endpoint detection. We made 49-point measurements on 50 monitor wafers with 5000Å of LPCVD Si_3N_4, using a Rudolph FEIII ellipsometer, to determine wafer-to-wafer (WTW) film thickness variability within a lot.

We used 5000Å LPCVD nitride monitors to gather our experimental data while minimizing handling times, thus producing more accurate etch rate data for COO modeling input. Later, we used a more typical thinner film thickness for actual COO analysis.

We processed the first lot of nitride monitors using 49% HF at 55°C with active endpoint detection to minimize overetch. The endpoint detection wavelength showed reproducible endpoint capability with a characteristic diminishing oscillation that stopped upon breakthrough to bare silicon (Fig. 1a). Post-etch measurements were made on the ellipsometer to ensure complete film removal. We used removal times for the endpoint lot to calculate a mean etch rate. Our data showed that the etch rate diminished linearly over time as the etchant was consumed.

We sent a second lot of monitors through the same process as the first lot without using endpoint detection control, although the endpoint detection system did collect data passively (Fig. 1b.) The amount of overetch this lot received was based on total thickness range across both lots to ensure complete film removal from every wafer; this is typical for critical pre-photolithography and pre-rapid thermal processing steps.

Unlike the first, we processed the second lot using a time correction feature of the spin-processing tool; this allows the diminishing etch rate of the chemistry to be corrected automatically by adding predetermined amounts of time. The time correction table for the second lot was derived from the linear trend line determined from the data of the first.

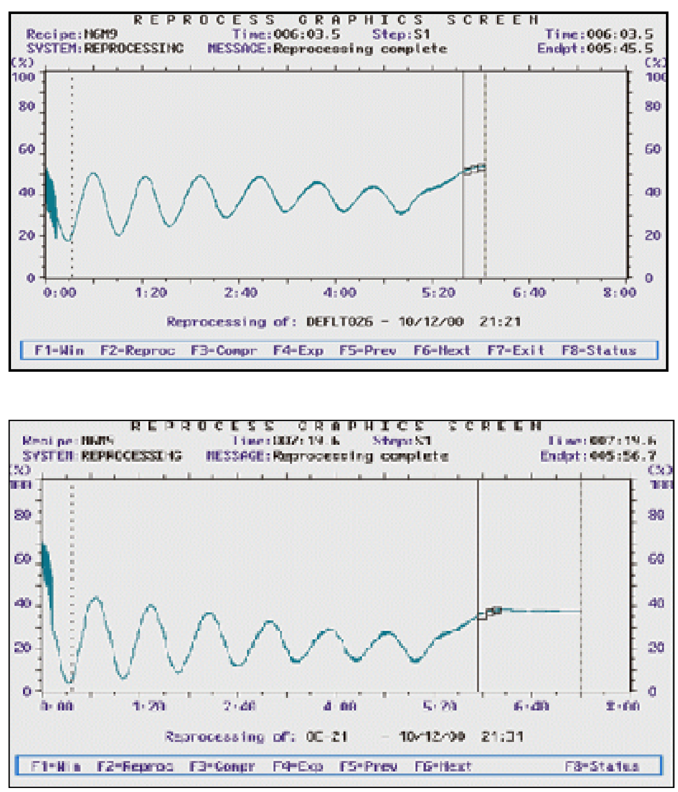
Figure 1 shows an example of scans obtained from each of the processes described above. It is clear that the overetched lot (using passive data collection) received a notably longer process time, well beyond endpoint.

Figure 1

Endpoint traces from a wafer in **a)** the endpoint lot and **b)** the overetched lot, the latter gathered passively (i.e., not controlling the process). The dashed line denotes the process stop point after endpoint detection. Note the substantial overprocessing found in b).

a)

b)



Because one of our metrics for this process evaluation was to be chemical consumption, we monitored the volume of the etchant in the tank of the spin processor during the etch process. We were now equipped with run time data from the tool's log files, etch rate data, and process chemistry consumption.

Cost analysis

We loaded our collected data into Wright Williams & Kelly's TWO COOL® v2.3 Cost of Ownership modeling software. Developing a workable COO model requires the application of pre-knowledge regarding typical process flow. Thus, we used a spin process that removes 2000Å of LPCVD Si_3N_4 from the backside of 200mm wafers. We also used SEZ standard reliability values (i.e., MTBF, MTTR, MTBA, etc.) as published in the spin processor tool specification.

The endpoint system reduces excessive overetch in a tool on a per-wafer basis, thus increasing the number of wafers that can be processed through a given tool/week. Using COO modeling — which gives wafer volumes in wafer starts/week — with a fixed utilization for both tools, wafer starts/week increased 12.5% from 2514 without endpoint to 2829 with endpoint. In our analysis, this increase in volume affected all of the cost drivers/GWE in the COO (see table below).

Clearly, a significant benefit from this COO analysis is the reduction of materials and consumables, in this case, process chemistry. In addition, a process that overetches for extended lengths of time unnecessarily adds exposure time of the chemistry to the exhaust, where a good portion is lost. With endpoint detection, there is a 28% increase in the number of wafers/liter and a saving of 14% in the amount of chemical used per day. With the standard overetch, 42 liters/day are being consumed at a rate of 9.37wafers/liter, compared to the use of the endpoint detection system, where 36 liters/day are being consumed at a rate of 12.63 wafers/liter.

All together, the cost drivers/GWE lead to an overall reduction in cost/GWE of 10.4% — from $3.46 to $3.10/wafer; 33% of this savings comes from reduced consumable materials (e.g., process chemicals).

Cost drivers on the management report of COO

	Costs ($)		Savings ($)
Cost drivers/GWE	With overetching	With endpoint detection	
Depreciation	1.315	1.245	0.070
Labor	0.746	0.664	0.082
Consumable materials (e.g., process chemicals)	0.626	0.505	0.121
Other materials	0.314	0.279	0.035
Maintenance	0.269	0.239	0.030
Support personnel	0.066	0.059	0.007
Floor space costs	0.065	0.058	0.007
Scrap	0.050	0.050	0
System qualification costs	0.004	0.003	0.001
Training	0.002	0.001	0.001
Total cost/GWE	3.46	3.10	0.360

Tool utilization

Utilization is a tremendous factor in the overall COO for capital equipment. For the past 18 months, chipmakers delayed new wafer fabs and expansion of existing facilities while they waited for clear signs of stronger growth in IC markets. Now, though, capacity is getting a bit strained, with fab capacity utilization running above 90% for the IC industry [2]. Capital equipment in a fabrication facility that is not being fully utilized is not paying for itself. However, constraints such as scheduled and unscheduled maintenance downtime, engineering time, etc., prevent any piece of equipment from reaching 100% utilization.

When production calls for an increase in wafer starts/month, it is often necessary to add capital equipment, which in turn reduces total utilization of all like tools. For example, if production demand on a single tool already has that tool running at 80% utilization (with a realized maximum of 95% utilization) and an increase in demand dictates a utilization increase that pushes total utilization over 95%, a second tool is required. The result is that the two tools then run at very low capacity, sending cost drivers/GWE to excessive levels.

As a viable alternative, our work has shown that the addition of in situ endpoint detection — for a capital investment much less than adding a new tool — can reduce cycle time by preventing unnecessary overetch and directly producing an increase in wafer throughput. This maximizes the use of a single tool and can lead to a substantial reduction in the overall cost/wafer (Fig. 2).

The sharp increases in cost/wafer in Fig. 2 indicate points at which an additional system must be added to meet required throughput levels. When comparing the overetching process to an endpoint process, the staggering effect becomes apparent. Should required throughput fall into these regimes, the addition of an endpoint system with minimal investment could eliminate the need for another tool, greatly reducing the cost/wafer.

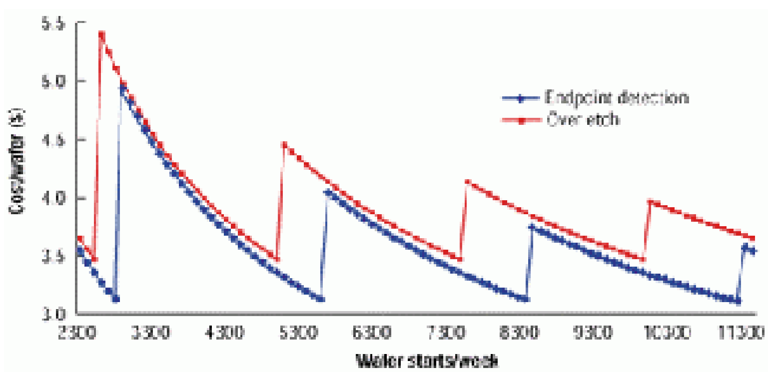


Figure 2. Cost/GWE at various wafer starts/week with an in situ endpoint detector and a standard overetch process.

Factoring in reworks

Our COO anlysis did not take into account any reworks for the standard overetch. The endpoint detection system will adjust for any film thickness that may go beyond the standard deviation that was calculated and adjust for drop in chemical effectiveness over time. The standard overetch formula and the time correction table, however, do not always allow for wafers with thicknesses outside the established parameters. This would create the need for some rework. Using an estimated 5% rework rate leads to a drop in GWE/week in the COO analysis (see Fig. 3).

The main reason for using in situ endpoint detection in wafer processing is for process control, which decreases chemical consumption and improves cycle time. The dispense time is shortened and less chemical is consumed/wafer. Cycle time improves because the endpoint detection system stops the process as soon as the film has been cleared off the wafer. This shortened cycle time increases throughput and decreases chemical consumption.

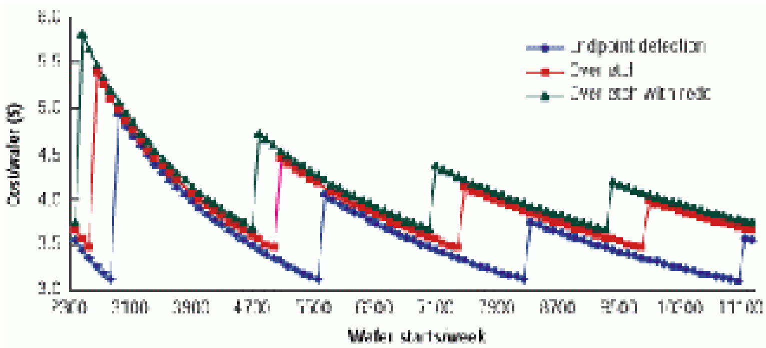


Figure 3. Cost/GWE at various throughputs/week with an in situ endpoint detector, standard overetch process, and standard overetch process with 5% rework rate.

This increase in throughput lowers COO on a per-wafer basis. This can be somewhat deceiving when looking at cost drivers on COO management. For example, depreciation of capital equipment is lower per wafer for the endpoint than for the standard overetch, when, in fact, the total cost of the capital equipment for the endpoint detection system is more than the standard overetch. This is explained with the increase in throughput. The endpoint detection system allows for more wafer starts/week, therefore, the depreciation is allocated over more wafers/year than the standard overetch, which lowers the cost/wafer.

Conclusion

Using in situ endpoint detection with spin processing provides tighter process control. In addition, such an equipment setup provides a 12.5% increase in throughput and, significantly, a chemical saving that allows for a 28% increase in the number of wafers/liter and a saving of 14% in the amount of chemical used per day. Such fundamental and incremental improvements, while often difficult, can be extremely beneficial: an increase in production as small as 1% can potentially result in increased sales of $200,000-$300,000/month for a semiconductor manufacturer [3]. Depending on a company's process, the actual numbers will vary, but clearly endpoint detection systems possess benefits other than just producing tighter yields.

References

[1] The Model 1015 has been replaced with the Optima 9225, but the two are functionallyidentical.

[2] J.R. Lineback, "Chip production gear: After three bad years, how big will the turnaround be?" Semiconductor Business News, Jan. 1, 2000.

Biographies

David B. Taraci received his BS in physical science from Northern Arizona University. He is field applications group leader for SEZ America, 4824 S. 40th St., Phoenix, AZ 85040.

Jerry T. Weston received his BS in marketing from Arizona State University. Weston is a member of the inside sales support team at SEZ America and determines cost of ownerships.

Fred Wertsching received his MS in solid state electrical engineering and his BS in biomechanical engineering, both from Arizona State University. He is a senior applications engineer at Luxtron Corp., 3201 N. 16th St., Suite 7, Phoenix, AZ 85016

New pad cuts slurry consumption, Thomas West claims

as reported by Semiconductor Online

1/2/2001 - The cost of ownership for a process tool is a combination of such factors as tool cost, operating cost, and maintenance. For chemical mechanical planarization (CMP), consumables are responsible for 61% of the total, according to Karey Holland, VP of technology for Thomas West, Inc. (Sunnyvale, CA). Polishing slurry accounts for two-thirds of all CMP consumables, Holland said. Tungsten slurry costs US$40-60/gallon (1 US gallon approx. 3.8 liters), and a single wafer can consume more than 250 ml.

The polishing pad, Holland explained, plays a key role in slurry consumption and distribution. Most pad designs use closed-pore polyurethane, sliced from a larger cylinder of the material. The pad won't hold very much slurry, so consistently high removal rates require correspondingly high slurry flow rates.

Thomas West's new line of pads, introduced in December, takes a different approach. Polyester fibers, coated with polyurethane, form a continuous pore structure. The material holds more slurry, and delivers it evenly over the surface of the wafer. Company CEO and president Thomas West claimed that the new pad can cut slurry consumption by 50%, while achieving the same removal rate as other CMP pads.

At the same time, the company claims the new pad can reduce oxide erosion during tungsten planarization by 50%, while delivering removal rate non-uniformity of only 3%.

Factory Explorer® v2.8 Released

Wright Williams & Kelly (WWK) is pleased to announce the release of its latest version of Factory Explorer®, version 2.8. Major improvements include:

1. Added capability to model tool states. This enhancement makes it possible to more accurately model cluster tools.
2. Added capability to split lots during processing. This enhancement allows for more flexible and detailed modeling of the process flow. Lots undergoing a mid-process split independently complete unload, delay, and travel of the split step and the remaining process.
3. Added capability to model physical input and output inventory buffers at each tool group. This enhancement enables more accurate modeling of WIP storage constraints. In particular, upstream blocking occurs when there is no availability in downstream input buffers.
4. Added capability to designate a specific operator group to perform setup. Separate operator groups may now be specified for setup, processing (load, process, unload), and travel.

This release is available at no charge to customers covered by warranty and maintenance agreements.

Grant Funds Faster Wafer Fabrication Research

Research currently underway at the University of Arkansas (UA) (Fayetteville, AR) may soon have a billion-dollar impact on the semiconductor industry. Scott Mason, assistant professor of industrial engineering, has received a $225,000 grant from the Semiconductor Research Corp. (SRC) for work that may revolutionize the fabrication of semiconductor wafers.

The SRC grant funds research to improve the scheduling and efficiency in the IC manufacturing process. Since IC manufacturers often deliver products late, manufacturers that can deliver on time will have a competitive advantage in the marketplace.

"This program expands the University's expertise to the front-end of wafer fabrication," explains Mason. "We already have a well-known program on the back-end--assembly, testing, and packaging--with our microelectronics and materials researchers, but industry is hungry for industrial engineers with a background in semiconductors. If we can improve efficiency and throughput by only one wafer per day, it will have significant effect. A typical wafer fab represents a $2 billion investment. Each wafer can be worth $50,000 to $100,000, and they are produced in lots of 25. At any given time, the inventory in a plant could exceed $0.5 billion."

UA, working with Arizona State University and the University of Wuerzberg in Germany, is developing scheduling methodologies for wafer fabrication that will incorporate methods to recognize and overcome problems that distort schedules such as bottlenecks, breakdowns, and other factors.

"Our goal is to make something that is actually used in industry, not to solve an academic problem," says Mason. "Our results should make scheduling a wafer fab on a shift-by-shift basis--or even more frequently--a real possibility."

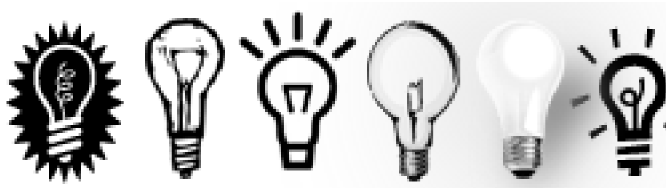
Wright Williams & Kelly Donates Advanced Manufacturing Software to University of Arkansas

Wright Williams & Kelly (WWK) has donated an advanced manufacturing software license to the University of Arkansas, Fayetteville. The product, Factory Explorer®, is the semiconductor industry's only integrated capacity planning, cost analysis, and discrete event simulation software solution. The license will be used for research in the Department of Industrial Engineering.

According to University of Arkansas Professor Scott Mason, "We are very excited to receive this gift. The contribution of Factory Explorer® is especially important to the Department of Industrial Engineering since it is state-of-the-art software currently used by many high tech manufacturers. Factory Explorer® will be used to support our ongoing research efforts in the modeling and analysis of semiconductor manufacturing systems. We thank WWK and look forward to making the most of this exciting new resource."

"WWK believes that the value of academic/industrial cooperation serves both communities well," states David W. Jimenez, WWK's President. "We are thrilled to support the outstanding research of Dr. Mason."

This spring, the Department of Industrial Engineering at the University of Arkansas will be celebrating its 50th anniversary. The department's faculty, graduate and undergraduate students are active in five of the six college areas of emphasis: Materials and Manufacturing; Electronics Manufacturing; Biological, Chemical, Food Processing; Environmental and Ecosystems Analysis; and Transportation, Logistics and Infrastructure. The department currently houses The Logistics Institute, the Mack-Blackwell Transportation Center, 270 undergraduate, and 50 graduate students.



For the suddenly energy conscious, a user's price guide...

As reported by Jason Margolis, CBS.MarketWatch.com

How much do energy costs run for various appliances? In the U.S., average kilowatts per hour is the uniform measure that determines how much power the average appliance requires, and thus, how much it costs to operate. Although the power necessary to run a microwave is the same in Virginia as it is in Wisconsin, the energy prices aren't uniform.

The following is a list of what it would cost to run certain home appliances based on calculations using California's Pacific Gas & Electric energy. While prices would vary nationwide, the basic ratios comparing one appliance to the next can be uniformly applied.

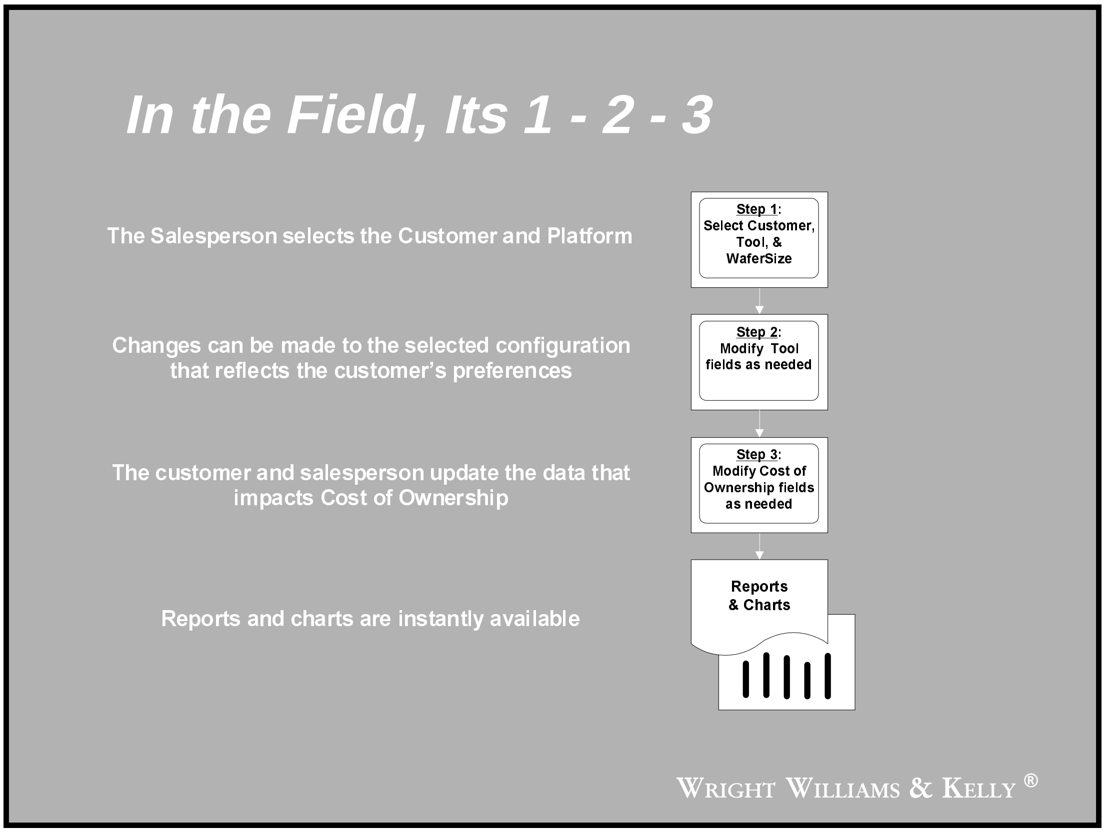
- Light bulbs are relatively cheap. Run a 22-watt fluorescent bulb all day and it'll cost you 6 cents. A 100-watt incandescent bulb costs 29 cents for the whole day.
- Heat up the home with a central furnace for 10 hours. In the San Francisco Bay Area that would run you $12.29.
- Likewise, want to cool the house during summer? Run a central air-conditioner 4-ton unit and it'll cost you 66 cents for an hour. Or use the ceiling fan instead for five days continuously at the same cost.
- Do a load of laundry with a gas-heated water, wash and rinse on cold - 5 cents a load. Use a warm/cold wash -- 9 cents a load. Hot/warm water -- 20 cents per load. Gas is cheaper than electric-heated water.
- Clean the dishes. Run the dishwasher with electric heated water - 37 cents.
- Gas heated water --16 cents. Run the cycle with "energy saver" -- save 2 cents in both cases.
- Make yourself a cup of Joe -- 2 cents to run the coffee maker.
- Have some waffles -- 5 cents for the toaster.
- 15-cubic-foot refrigerator, pre-1992 model -- $19.50 a month. Post-1992 model -- $11.70 a month.
- Heat leftovers for 10 minutes in the microwave -- 3 pennies.
- Entertainment is cheap. Watch 10 hours of television, on a 27-inch set, for 11 cents. Ten hours of movie watching on the VCR will only set you back 2 cents. Listen to the stereo for 10 hours -- 6 cents.
- Blow your hair dry. That'll cost you a nickel. A dime to vacuum the house.

WWK Introduces New Software Package for Sales Force Optimization

Valid product configurations, accurate pricing, and integration with cost of ownership calculation engines are the result of WWK's newest product, COOL FUSION™. This new product empowers your organization's field sales force with a simple to use tool that delivers fast, accurately priced, custom product configurations. COOL FUSION™ leverages the power of TWO COOL® the industry standard cost of ownership (COO) model.

COOL FUSION™ is a dynamic programming platform that allows you to describe the way YOU do business and then it adapts to you, not the other way around. Your specific product configurations are defined and mapped into COOL FUSION™. The result is a sales tool completely customized to your specifications. The application provides a concise, customized user interface that allows sales personnel an ultra-quick learning curve. They can be up and running in minutes, providing their customers with real time, value-added information instead of spending their time trying to track down relevant data and prices.

In fact, there are only 3 simple steps to getting all this information as illustrated below:



In order to manage the continually changing product data and prices within a worldwide sales force, WWK provides an Internet enabled solution. This means changes to your data are seamlessly and quickly distributed to your sales force from one single, centralized source.

Time is money and more than ever WWK is developing solutions to enable the power of information to get where it needs to be.

COOL FUSION™ will differentiate your sales force in the market while providing these significant benefits:

- Increase valuable customer face time
- Increase sales credibility
- Quickly build value propositions for your customers
- Reduce product configuration and pricing errors
- Reduce COO support requirements in Marketing

For more information on COOL FUSION™ or to see a demonstration, please contact WWK at (925)-485-5711. Providing decision tools for productivity and cost management since 1991.

TWO COOL® v2.5 for Mask Manufacturing Released

Wright Williams & Kelly (WWK) has announced the release of its latest version of its flagship cost of ownership (COO) and overall equipment efficency (OEE) software, TWO COOL® for Mask Manufacturing. Enhancements included in this software release include: learning curve anlaysis of materials and consumables, conformance to SEMI E79-0200 (OEE standard), expanded sensitivity curve outputs, report on two column model column deltas, and database history tracking. This release is available at no charge to customers covered by warranty and maintenance.

Wright Williams & Kelly to Exhibit at SEMICON West July 16-18 Moscone Hall North • Booth 6574

See Demos of . . .

TWO COOL® • PRO COOL® • Factory Commander™ • Factory Explorer® • and the new, revolutionary Sales Force Automation software COOL FUSION™

Wright Williams & Kelly will also hold the following seminars at SEMICON West . . .

How to Successfully Manage New Product Introductions - a 2 day seminar,
- July 13-14

Understanding and Using Cost of Ownership - a 1-day seminar
- July 17 in San Francisco
- July 19 in San Jose

Register at http://www.semi.org