# Improving PWB Productivity By Reducing Process Cycle Time

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**Abstract**
Printed wiring board manufacturers are becoming more dependent on time as a competitive variable. Fabricators of any size can profit from products that have the capability to improve productivity by reducing cycle time. By allowing more lamination volume per press per day, fast-cure prepregs enable improvement in manufacturing productivity and profitability.

In an environment of fluctuating production volumes and intense cost containment, efficient utilization of installed capital base is a more attractive option than capital expenditure. New press installation and operating cost structures can be substantially higher per square foot for multilayer boards than application of faster curing prepreg that optimizes current press capacity.

Facilities that specialize in quick-turn and prototype work achieve a price premium for accelerated production cycles. In servicing their customer base, these shops accommodate more variation in lead times, order volumes, and product range. Significant reduction in press cycle time creates further advantage.

This paper is a discussion of a new FR-4 prepreg, Isola Laminate Systems' ZipCure™, which enhances the competitiveness of PWB fabrication by reducing time in the lamination process through a faster cure. In addition to reduced processing and capital costs, other benefits include higher yields, better thickness tolerance and improved CAF resistance. This prepreg derives its accelerated cure properties from an enhanced resin system and manufacturing technique that generates nearly 100% wet-out in most glass styles.

**Purpose**
We are looking for a method to solve one of the most important problems facing any PWB business: How do you take cost out of the manufacturing process? The method proposed in this paper is to address one of the most costly steps in the process. A breakdown of PWB manufacturing costs is presented in Figure 1.

A quick glance at Figure 1 shows that pressing contributes 20% of the cost of manufacturing PWB. It is this portion of the value chain that fast-cure prepregs attack, and the reduction in cycle time is substantial.

**Cycle Time**
Cycle time is the heartbeat of production. Simply stated, it is the amount of time needed to produce a unit of product. For circuit board manufacturers, an obvious example of cycle time is the lamination press cycle. For instance, if a press recipe is two hours long and 1000 panels are produced, the cycle time is two hours/1000 panels or 7.2 seconds per panel.

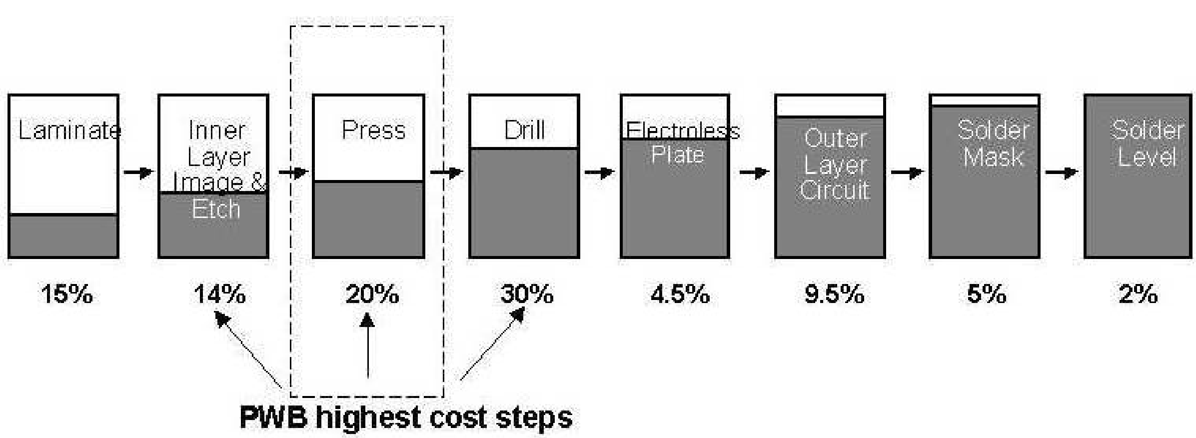


**Figure 1 – Breakdown of PWB Manufacturing Costs**

What is the impact of cycle time reduction? It depends upon many factors, but the most remarkable is when the cycle time through the process constraint is reduced. Specifically, if a shop is press-constrained, a reduction in cycle time leads directly to an increase in throughput. Figure 2 demonstrates how a 32% increase in production can be achieved by lowering the press cycle from 90 minutes to 60 minutes using this fast-cure prepreg.

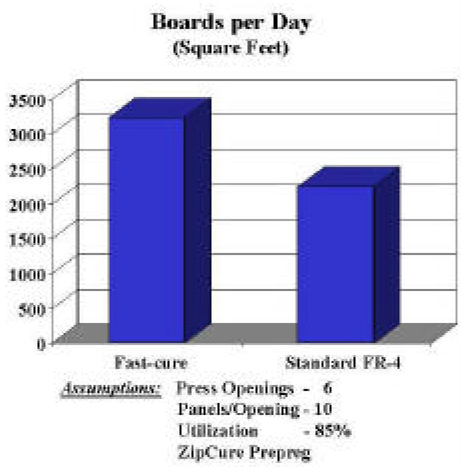


**Figure 2 – Example of Throughput Increase Due to Press Cycle Time Reduction**

If the press is the bottleneck, why not purchase another press? Obviously, an additional press would require a capital expenditure, and the additional cost is not necessarily justified. Figure 3 demonstrates how purchasing an additional press leads to an increase in production cost of $1000/day relative to implementation of this fast-cure prepreg. Fast-cure prepregs allow a shop to gain volume immediately without capital expenditure. Consequently, the shop avoids carrying a larger asset base that is more difficult to support when the market is soft.

If the press is not a constraint in the manufacturing process, the justification for press cycle time reduction comes from increased manufacturing flexibility and better resource allocation. Many board shops realize a premium for quick-turn jobs. For quick-turn work, every minute counts as the jobs are expedited through the shop. A fast-cure prepreg will allow for a shop to accept more quick-turn work for the same amount of time, or to shorten the lead-time on the quick-turn work they currently receive. Finally, with less time being spent at the press, operators will have more time to help with other work that needs to be done.

## Value Model
### Cost Avoidance

| | | | |
|---|---|---|---|
| *CURRENT PRESS CHARACTERISTICS* | | | CURRENT |
| Press Cycle | | | 75 |
| Loads/Day (85% Utilization Rate) | | | 16.3 |
| Panels/Book | | | 10 |
| Book/Load | | | 6 |
| Panels/Day | | | 979 |
| Board SF/Day (18x24) | | 3 | 2,938 |
| ***INITIAL EQUIPMENT COSTS*** | | | |
| New Press - Equipment Cost | | | $ 1,000,000 |
| Installation Cost (% of Purchase Price) | | 20% | $ 200,000 |
| Total Cost for installed Press | | | $ 1,200,000 |
| ***ANNUAL OPERATING COSTS*** | | | |
| Depreciation | Years = | 7 | $ 171,429 |
| Investment | Interest = | 8.0% | $ 96,000 |
| Service Contract | | $ 4,000 | $ 4,000 |
| Power Consumption (Per Cycle) | | | |
| Electric | | $ 5.04 | $ 24,676 |
| Gas fired Hot Oil or Steam | | $ 0.63 | $ 3,084 |
| TOTAL ANNUAL OPERATING COSTS | | | $ 299,189 |
| ***TOTAL COST AVOIDANCE*** | | | |
| TOTAL increased Cost per SF | | | $ 0.34 |
| Total increased Cost / Day | Days= | 300 | $ 997 |

**Figure 3 – Capital Avoidance Comparison**

**Performance**

The impact of fast-cure products can be demonstrated by several methods. First, the Gel Time of this fast-cure product is substantially shorter than standard FR-4 products, as demonstrated in Figure 4.

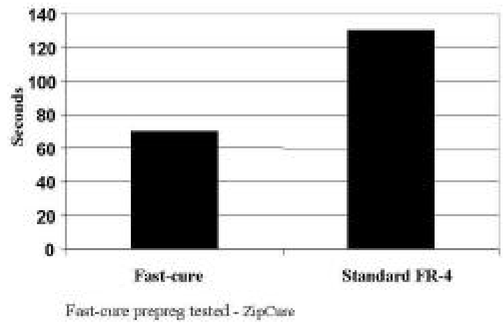


**Figure 4 – Gel Time of Fast-Cures vs. Standard FR-4**

Typically, a shorter gel time creates anxiety due to concerns regarding the ability to flow and fill between the circuits. This fast-cure product solves the problem by creating a thermal profile similar to standard FR-4 over the lamination cycle, but with faster reaction kinetics late in the cycle. This allows the fast-cure product to flow like the Standard FR-4 early in the cycle, but accomplish complete cure in less total time. The effect can be more clearly demonstrated in Figure 5.

Notice that the curves for this fast-cure product closely resemble the Standard FR-4 product, especially at the faster heat rises. Additionally, the minimum viscosity, and hence the time of peak flow, occurs within a few minutes of each other. This fast-cure product delivers both the wide flow window of the Standard FR-4 and a faster overall reaction.

**Mechanics**

Another advantage of this specific fast-cure product is the degree of wet-out. Ideal glass impregnation would yield a complete replacement of gas from between the glass bundles with resin. Standard FR-4 glass systems are typically less than optimally impregnated. Any trapped volatiles must be removed or collapsed during the lamination cycle. When impregnation is marginal, the circuit configuration is challenging, and the presses are not optimized, the entrapped volatiles can expand during lamination to cause blisters and delamination.

This fast-cure prepreg solves the wet-out issue with improved impregnation. This is accomplished with a mechanically enhanced treating process that ensures more complete gas replacement. The difference can be seen when observed under magnification as in Figure 6.

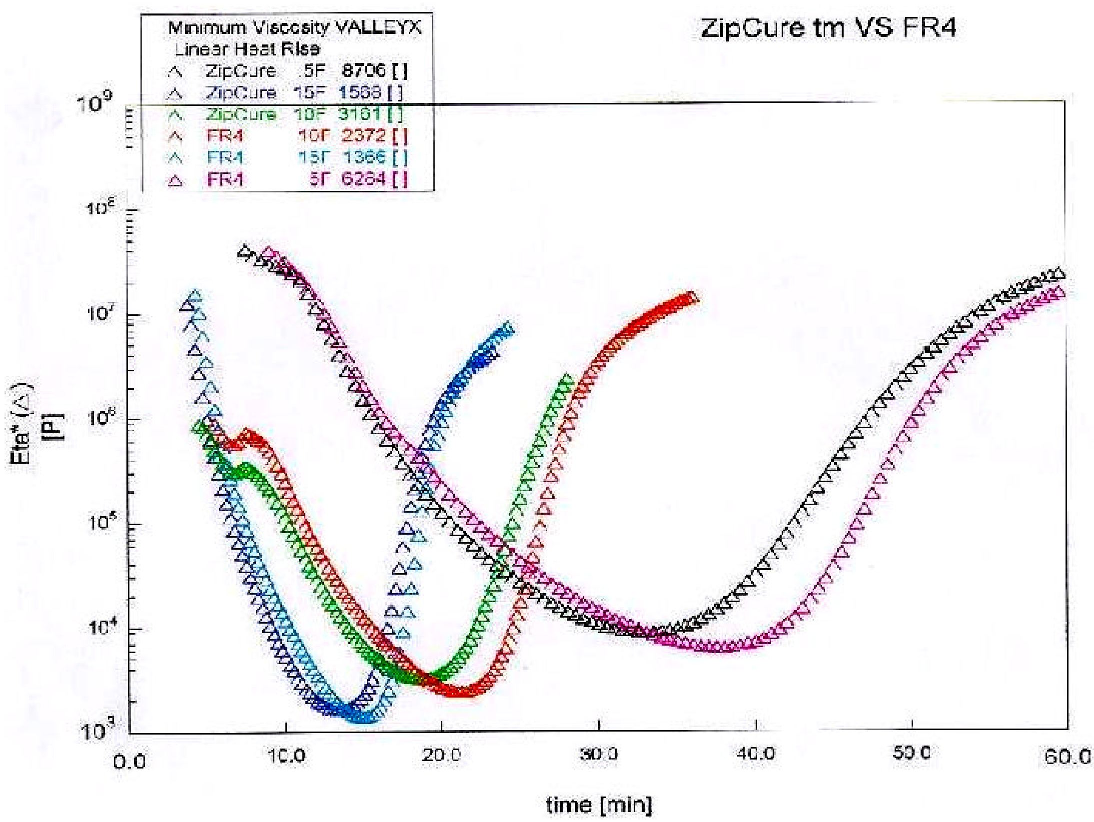


**Figure 5 – Thermal Viscosity Curves for Fast-cures vs. Standard FR-4**

The enhanced impregnation yields other desirable product characteristics, namely less dry weave and greater thickness control. The improvement in dry weave stems from the combination of improved wet-out and more advantageous reaction kinetics. The impact is substantial on traditionally challenging glass styles like 7628. A picture that demonstrates the improved flow results is provided in Figure 7. The improved wet-out of this product should also improve CAF resistance. Testing to prove this is in progress.

With the improved flow characteristics there is a concern that thickness control will be compromised by loss of resin off the side of the panel. This particular fast-cure product has been designed with this concern in mind. Specifically, the loss of thickness towards the edge of the panel, commonly known as taper, is equivalent to, and sometimes better than, the standard FR-4 products.

Figure 8 depicts the standard deviation of panel thickness profile measurements for several glass styles of both Standard FR-4 and the fast-cure product. Notice that in this case the fast-cure standard deviations are more consistent across product lines, and small overall. The reduced dryness is accomplished without unnecessary loss of resin. More resin is retained in the package, and the resulting product measures more uniform thickness. The characteristics of the fast-cure product make it ideally suited for applications with tight controlled impedance requirements.

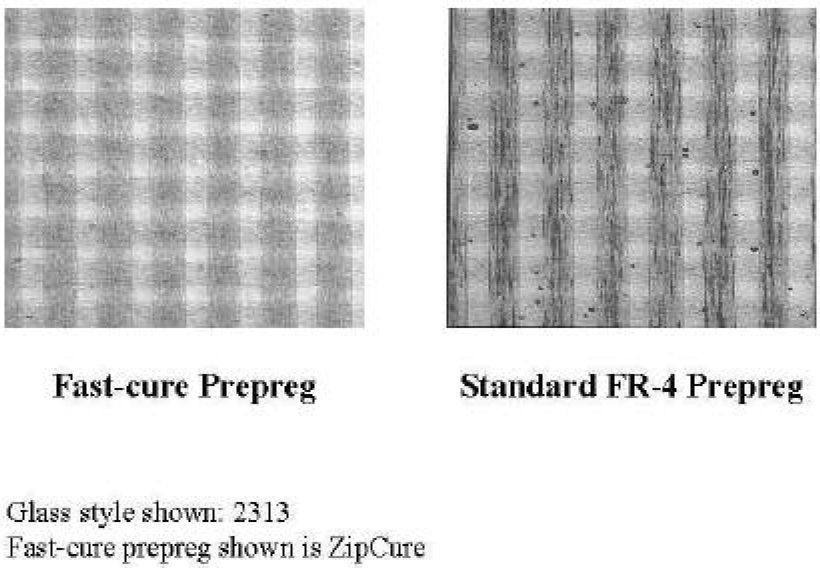


**Figure 6 – Impregnation of 2113 Glass**

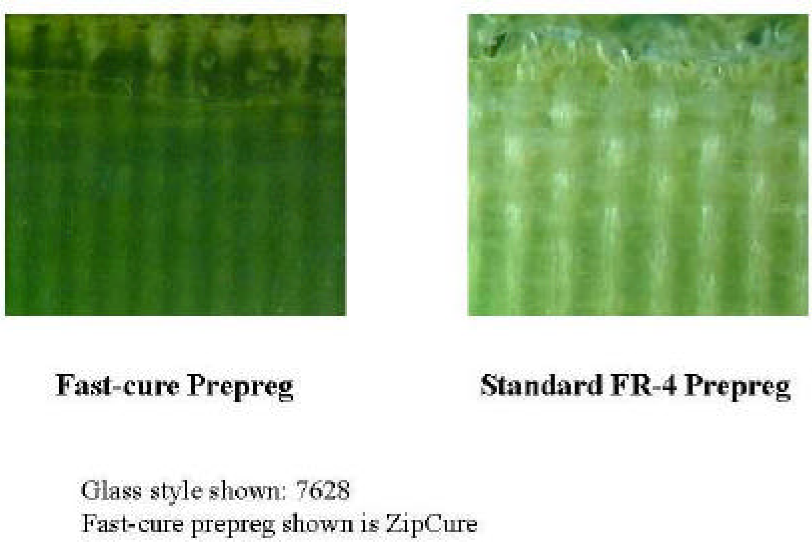


**Figure 7 – Functional Test Dry Weave Results**

**Processability**

The product has been tested in several North American board shops, and the processing requirements and performance have been comparable to standard FR-4 products. It is fully FR-4 UL qualified, and the Tg of the product is 150° when processed under recommended conditions. Operators report that the product sheds less dust at stack-up than standard FR-4 products. Press cycles as short as 60 minutes yield good product. This fast-cure product processes acceptably with standard FR-4 board shop parameters, and the performance can be improved over standard FR-4 performance with minor adjustments to standard lamination and drilling parameters.

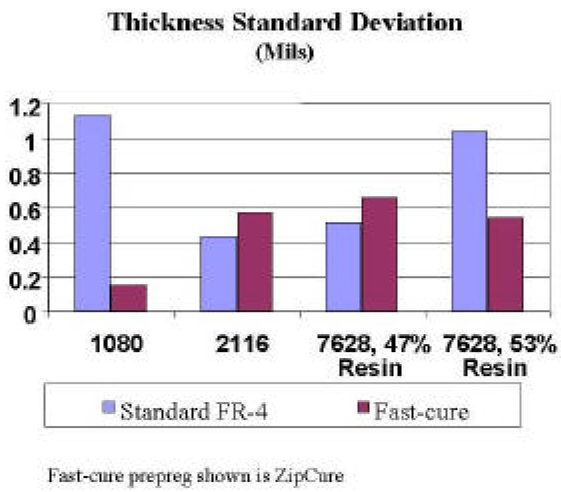


**Figure 8 – Functional Test Dry Weave Results**

**Conclusion**

As pressure mounts for better financial performance, PWB shops will have to find creative ways to take cost out of the product. Opportunities exist for laminators and board shops to work together for mutual benefit. Fast-cure prepregs provide a mechanism to make more boards per press, bolstering throughput and improving the bottom line.

**Reference**


1. ZipCure is a trademark of Isola Laminate Systems Corp.