HCHO Emissions Debate Invites Scrutiny Of Lab Tests, Economics

Economist states that production of low HCHO emitting boards based on UF resins is technically possible and economically preferable.

By Henry Spelter

For longevity, few issues in the forest products industry rival the formaldehyde (HCHO) debate. The issue came to the fore in the mid-1970s as increased use of HCHO-emitting board products in more tightly constructed homes led to numerous complaints. As a result, U.S. Housing and Urban Development Agency (HUD) ruled in 1985 that the HCHO level of air in mobile homes would be limited to 0.4 parts per million (ppm) to be accomplished by limiting HCHO emissions from particleboard and plywood to 0.3 and 0.2 ppm, respectively (source: Margosian ‘86).

Similar problems in Europe enticed the German health ministry in 1980 to set a guideline limiting the emission of HCHO in construction particleboards to 0.1 ppm, the well known E-1 classification. Higher HCHO-emitting particleboards, those used for furniture and classified as E-2 or E-3, were required to be sealed with laminates, which serve as barriers to gas movement (Ernst ‘82).

For particleboard producers, the HCHO issue posed marketing as well as environmental challenges. Field reports indicated that “problems with formaldehyde offgassing have created (mobile home) manufacturer interest in products bonded with phenolic resins” (Anderson ‘83). In response, producers modified their process to significantly reduce HCHO emissions (Fig. 1).

Notwithstanding these advances, regulatory concern about HCHO continued. In May 1984, EPA initiated an investigation based on its conclusion that there might be a significant health risk to occupants of homes containing wood products. In April 1987, EPA formally classified HCHO as a “Group Bl probable human carcinogen.” In June 1991 EPA published an Agency Options Paper in which a ban on HCHO-containing flooring products under regulatory authority was discussed along with certain labeling requirements for other products. The issue was poised to come to an important point this past November with the posting of a Notice of Proposed Rule Making (NPRM). This was expected to call for a ban on the use of urea formaldehyde (UF) in pressed boards made for flooring. While such an outcome is still a possibility, industry and EPA representatives have continued to meet with the expectation that a set of voluntary guidelines for the amelioration of HCHO in pressed wood products will be worked out by spring 1992.

This article reviews the main points of contention between regulators and producers. Discussions are ongoing, and positions attributed to EPA are not final. Data attributed to EPA here were obtained from an industry position paper (Murray ‘91).

Test Methods

In the course of the controversy over the use of HCHO containing resins, the HUD emission standard of 0.3 ppm and the seemingly stricter German E-1 standard of 0.1 ppm have been compared. Both standards refer to HCHO concentrations measured inside large chambers, but the test protocols differ. On average, the German Wilhelm Klauditz Institute (WKI) chamber test results are 20% lower than the U.S. FTM-2 tests (Fig. 2). The relationship between the two tests can be summarized in equation form (Groah ‘91): FTM-2 chamber = 0.015 + 1.22 x WKI chamber.

For quality control, simpler methods are required. In Germany the perforator test is prescribed in which HCHO in 100 g of board is extracted by boiling in toluene. The HCHO in the solution is then determined by an iodine titration procedure (iodometric method). A value of 10 mg or less is required for E-1 certification. The 10 mg value should then correspond to the 0.1 ppm chamber limit (Ernst ‘82. Groah ‘91).
is because the iodine reacts not only with formaldehyde, but other oxydizable substances extracted from the board along with the HCHO. This can be especially critical at low values of HCHO content (Roffael and Mehlhorn '80).

Further, the perforator test is sensitive to board moisture content (MC) (Jann and Deppe '90). Although the German guideline did not specify a board MC, its limit of 10 mg/100 g corresponds to a chamber value of 0.1 ppm for a MC of about 8% (Jann '91). Because boards are normally tested soon after pressing, when MC is closer to 6.5%, depressed readings often ensue. For these reasons, the European guideline for HCHO determination has recently moved away from the iodometric method to an alternative, so-called photometric method with a specified MC requirement (of 6.5%) for the board sample.

Relationship between perforator values (derived by the photometric method) and the WKI chamber test was estimated (Grosh '91). Since the perforator values under the new procedures have not been finalized yet, it’s necessary to convert this formula to the old iodometric basis (using a conversion equation obtained from Sundin (Sundin '90): WKI chamber = 0.11 + 0.028 x Perforator (iodometric, 6.5% MC).

Because the conversion of interest is from a standardized (8% MC) iodometric perforator value, such values are first converted to a 6.5% basis, for use in the above equation. by dividing by 1.257 (derived from Jann '91).

These formulas can now be used to convert and compare different benchmarks (Table 1). For example, the HUD 0.3 ppm value corresponds to a 0.233 ppm WKI value and a 15.54 mg/100 g perforator estimate. In contrast, the HUD equivalent of the 0.1 ppm European standard is 0.137 ppm. The FTM-2 chamber test equivalent of the perforator limit is 0.153 ppm. European equivalents of current U.S. industry averages for HCHO emissions are also given in Table 1. Although U.S. HCHO emission levels, on the average, do not meet European standards, the gap between the two is closer than the unadjusted difference in standards would suggest.

### Exposure Measurement

Health risk is assessed by the time and amount of HCHO exposure at levels greater than the generally accepted safety limit of 0.1 ppm. EPA uses several scenarios to frame the exposure range, based upon varying amounts of HCHO-emitting pressed wood products in varying home types. In the EPA scenarios with two mobile home and six conventional homes, time exposures greater than 0.1 ppm range from two to six years (Semeniuk '91). Table 2 contains one such estimate of 2.7 years, as calculated by industry based on one set of EPA inputs.

In contrast, corresponding industry inputs yield three months. The main disagreements between EPA and industry involve (1) half-life of HCHO emission decay, (2) average ambient home temperature, (3) background HCHO concentration, and (4) time between production and consumer exposure.

Formaldehyde liberation decreases over time as the amount of free HCHO is exhausted. To estimate the decay curve, EPA relied on measurements in homes using home age as a proxy for decay. Industry faulted this approach for not discriminating among differences in the mix of HCHO emitters, such as carpeting, upholstery, and drapery. In contrast, a controlled study of industrial boards indicated an average half-life of seven months (Zinn '90). The EPA discounted this study because the board samples were stored in low concentration HCHO environments between tests, which tended to accelerate the decay curve. Industry then cited a controlled European study in which boards were wrapped in polyethylene foil between testing intervals. This gave a one year half-life for class E-I particleboards (Sundin and Roffael '89).

Because HCHO emissions are temperature dependent, home temperature assumptions are important. Industry believes that the 25° C (77° F) assumed in the exposure simulations does not reflect actual average conditions in homes, but rather is a regulatory artifact tracing back to the original chamber tests used by HUD. Industry cited a 20° C to 23° C (68° F to 73° F) range used for conducting chamber tests in various European countries and noted several studies indicating average U.S. home temperatures of about 23° C (73° F).

The background HCHO concentration is also disputed. EPA uses 0.05 ppm, whereas industry maintains that 0.03 ppm is more appropriate. A high background concentration increases the initial loading of HCHO, which increases the time required to achieve a level of 0.1 ppm. Industry presented data to EPA from a study of homeowners who had not complained of emissions in which the HCHO levels ranged from 0.027 to 0.040 ppm.

Finally, industry representatives argued that the high initial emission phase should be discounted because it does not occur in occupied homes, but in transit, inventory or unfinished structures. The EPA regards chamber HCHO emission test values as appropriate starting levels, because they are normally taken within one month after the boards are produced.

### Economic Impact

Of the two likely alternatives, a UF ban or an E-I-type standard of 0.1 ppm, it’s generally agreed that the ban on UF would have the greatest economic impact. In the event of a ban, phenol formaldehyde (PF) would be a logical alternative, but PF has several disadvantages. Aside from costing about two and a half times as much. PF has a higher water content that would have to be offset by increased drying of particles, and requires longer press times and higher press temperatures. Process impacts can be analyzed by means of the profit equation: Profit/Time = Output/Time x (Revenue-Cost)/Unit Output.

Preliminary EPA estimate of the incremental cost of switching from UF to PF
was $70/MSF ($0.75/m^3) (¾ in. (19 mm basis)), whereas industry estimate was more than $100/MSF ($1.08/m^3).

A major consideration is the amount of capacity that would be lost. EPA calculated a capacity reduction of 29% but a 20% drop in output (from 95.2 to 76.4 MSF (8.84 to 10 m^2)) due to greater capacity utilization. However, industry estimated lost capacity at 36%.

Based on an independent estimate of 30% output loss (Femea ’91). I estimate the cost increase at $74/MSF (Table 3). This is also based on a 7% resin use and the assumption that, as in waferboard mills, PF resins would be partially substituted for by less expensive lignins (Sellers ’90). For example, “organosols” lignin, derived from an experimental panel making process and costing about $0.25/lb. ($0.55/kg), is used in a few waferboard mills and one plywood mill to replace about 20% of the PF (Henry ’91). A 20% substitution by this or similar resins would keep resin costs at less than $0.35/lb. ($0.77/kg). Under these assumptions, a roughly $1.4 million annualized profit converts into a $3.9 million loss. Prices would have to increase to $275/MSF ($296/m^2) (+41%) for the same level of profitability. These figures exclude any plant conversion expenses that may be needed to accommodate PF resins.

To meet a more stringent emission standard similar to the European E-1 of 0.1 ppm would require one or a combination of several techniques: (1) using resins with a low (1.2 or less) molar ratio of HCHO to urea, (2) adding scavengers (such as urea or ammonium carbonate) to the resin or furnish, or (3) post-treating of panels with HCHO scavengers (such as ammonium carbonate or simply by aging the boards) (Myers ’86). Options (1) and (2) are the primary techniques employed. Both measures would probably result in a loss of some capacity, although only on the order of 5-10% (Femea ’91). Resin costs would also rise. For example, adding urea to furnishes increases resin costs by about 5% or total costs by about $2/MSF ($0.22/m^2). But the overall impacts on economics are milder (Table 3).

Further developments may reduce the impacts even more. One European supplier offers a scavenger that has adhesive properties of its own, meaning that it can be used as a resin substitute rather than as an additive. Up to 25% of the UF can be substituted on a 1 : 1 ratio (Markessini ’91). Because the cost of the scavenger is about 80% of the cost of the resin, the process saves about 3% in resin costs in addition to the 5% savings from not using a urea scavenger. In combination with a low molar ratio UF resin, a perforator value of 8 mg/100 g is claimed, which translates to a FTM-2 chamber value of 0.097 ppm.

Using some combination of these techniques, particleboard producers can decrease the free-HCHO content of boards. For example, where European manufacturers naturally aimed at a perforator test value of 10 mg. Swedish boards tested a few years ago at the German Wilhelm Klauditz Institute registered MC-adjusted (to 8%) iodometric perforator values as low as 5.2 ppm without deterioration in board properties (Sundin ’89).

Conclusions

A review of UF adhesives technology shows that production of low HCHO emitting boards based on UF resins is technically possible and economically preferable to using PF resins. In the contemporary German particleboard industry, boards are almost exclusively produced to E-1 standards. In 90% of the cases, this is accomplished with low molar ratio UF resins used in combination with HCHO scavengers (Roffael and Boehme ’91). In the U.S., the HCHO issue is heading toward a resolution. The outcome will likely be stricter limits on allowable HCHO emissions. The remaining question is by what means.

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