An Epidemiologic Study of Respiratory Health Effects in a Group of North Carolina Furniture Workers

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Woodworking is known to be associated with nasal cancer and with western red cedar asthma, but research is inconsistent with regard to respiratory health effects among furniture workers. The authors tested the hypotheses that employment in a North Carolina hardwood furniture plant was related to the prevalence of respiratory symptoms and to impairment of pulmonary function. Chronic symptom prevalence generally showed no significant differences between wood dust jobs and control exposures; however, frequent sneezing and eye irritation were significantly ($P < .05$) correlated with wood dust exposed jobs; in both cases the prevalence odds ratio was 4.0. Peak flow was the only pulmonary function measure that correlated significantly ($P = .0345$) with wood dust employment. The difference in forced vital capacity suggested a weak association with current employment in finishing jobs, whereas the difference in peak flow showed a modest correlation with the fraction of particulate <10 μm. The relevance of the present associations to regulatory changes and research needs is discussed.

Employees in woodworking occupations are known to suffer from diseases and symptoms in the respiratory tract that are correlated with wood dust exposure. Examples include western red cedar asthma and rhinitis,[1] adenocarcinoma of the nasal sinuses,[2] and nasal mucostasis.[3-5] Many case studies of workers handling hard and soft woods have described bronchospastic reactions to extracts or aerosols of inhaled wood dusts.[6,7] A limited number of epidemiologic studies have reported elevated prevalence of pulmonary symptoms among soft wood mill workers[8,9] and declines in baseline pulmonary flows and volumes among pine, hardwood, and mixed-wood furniture workers.[10-13] However, until the present study, there had been no epidemiologic studies of the furniture industry in the southeastern United States, which is the region where most of the industry is concentrated. The purpose of this paper is to describe the results of the first study of symptoms and pulmonary function in a southern furniture plant using a variety of hardwoods; we hypothesized that workers exposed to wood dust had a greater prevalence of respiratory symptoms and a greater risk of impaired pulmonary function than workers not exposed to wood dust.

Methods

The study was conducted by the University of North Carolina Department of Epidemiology at a North Carolina furniture plant having about 350 employees. As seen in the Figure the plant's material flow is straightforward: wood is received from suppliers, dried in kilns, cut and sanded, assembled into furniture, finished, inspected, and shipped. The study plant did not produce upholstered products, although it installed upholstered pieces such as seat cushions on chairs. At the time of the study (late 1981), the company produced living room, dining room, bedroom, and office furniture, including chairs, desks, tables, and auxiliary pieces. The plant used common and exotic hardwoods such as white oak (*Quercus spp.*), maple (*Acer spp.*), walnut (*Juglans nigra*), yellow poplar (*Liriodendron tulipifera*), fiberboard, mahogany (*Swietenia macrophylla*), and andiroba (*Carapa spp.*), a less expensive tropical hardwood resembling mahogany.

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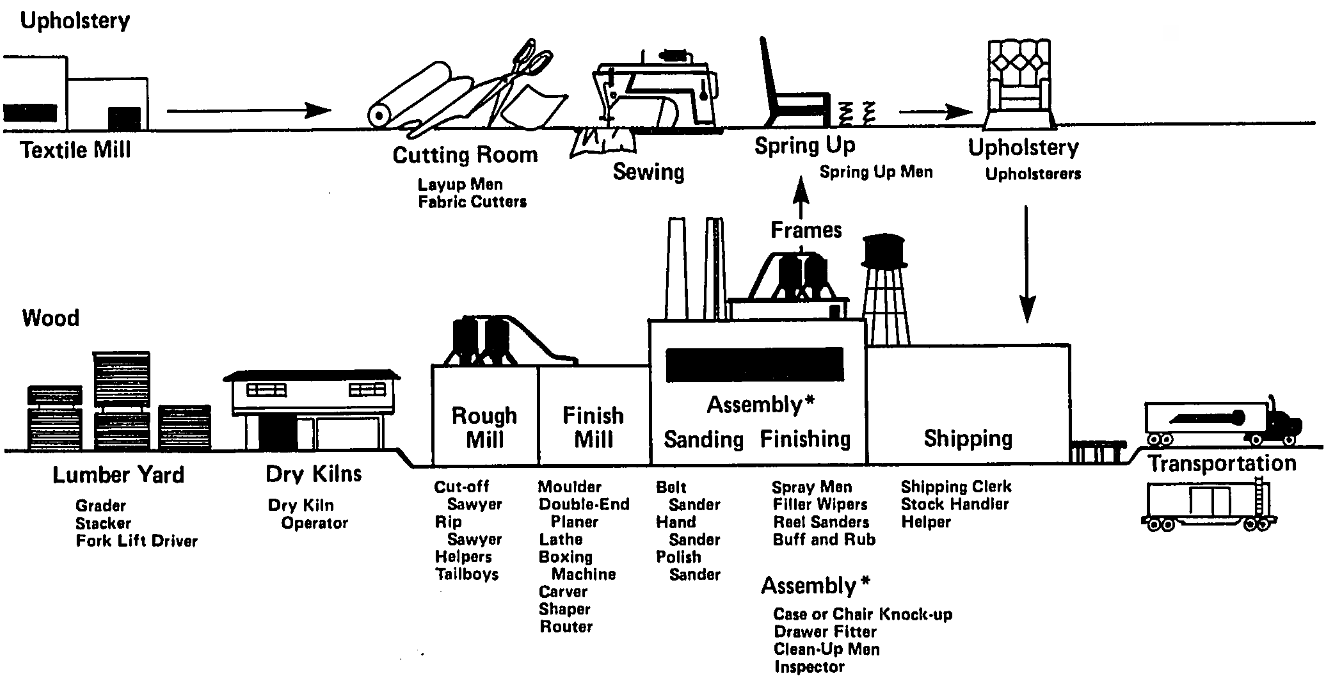

Figure. Manufacturing of wood furniture. (Material adapted from ref 14.)

We randomly selected about 100 employees to participate in the study from three groups of workers who had worked at least 1 year: those with wood dust-exposed jobs (sawyers, carvers, cutters, and sanders), those working in the finishing rooms (where dust is not permitted because it ruins the finish), and those unexposed to either wood dust or finishes (jobs such as yardmen, shippers, and office workers). After consent to participate in the protocol was obtained, each subject was administered a standardized questionnaire[15,16] (expanded slightly to query for acute symptoms reflective of "woodworkers asthma"[17]), eliciting demographic information; smoking, medical, and work histories; and respiratory disease symptoms. Work histories were obtained from company personnel records and all relevant furniture industry employment was summed to provide a cumulative work record. Each employee's height, weight, and pulmonary function were measured. Pulmonary function testing (PFT) was conducted before and after work using five maximum blows into an Ohio 800 rolling seal spirometer. From these blows, the maximum envelope was used to generate baseline and difference measures of lung function: forced expiratory volume in 1 sec (FEV_1), forced vital capacity (FVC), peak flow, forced expiratory flow at 50% and 75% of capacity (FEF_{50} and FEF_{75}), and the ratio of FEV_1/FVC.

Based on work by Colangelo,[18] we conducted area-wide particulate sampling using a Marple impactor among two groups of workers having either wood dust exposures with high mass concentrations and small particle sizes (sanders) or lower mass concentrations and larger particle sizes (sawyers, carvers, drillers, routers, and planer operators). In addition, we sampled particulate levels among two groups of workers where the dust levels should have been low: finishing workers and employees unexposed to wood dust or finishes.

Measuring the associations between PFT and symptoms and exposures in the furniture industry requires that adjustments be made for the known determinants of these pulmonary endpoints. The most powerful determining factors are age, sex, and smoking (and height for PFT).[19] To determine the effects of wood dust exposure we examined acute and chronic symptom responses using logistic regression[20] adjusting for age, sex, and pack-years of cigarette smoking. For the correlation between baseline PFT and exposure, we used linear regression analysis,[21] adjusting for known covariates—age, sex, height, and pack-years—and examined other potential confounders, such as prior employment in jobs having pulmonary hazards, hobbies with potential for hazardous exposures such as furniture refinishing and construction work, medical history of chest injury, alcohol use, and atopic status. All computer analyses were run using SAS software.[22]

The independent factors studied in the baseline regressions were present jobs with exposure to wood dust or to finishes, cumulative person-months employed in wood dust jobs or in finishing jobs, and interaction between smoking and either wood dust or finish exposure. Because the company had recently installed a new exhaust system after an accident that closed the plant, we assumed that measured dust levels were not an accurate reflection of past concentrations; therefore cumulative dust exposure (based on length of employment) was not examined as a test variable. Health effects among workers exposed to wood dust and finishes were compared with unexposed workers.

Because we assumed that both wood dust or finish exposure could have had subtle diurnal effects on respiratory function over the work day, we used step-wise regression for analysis of acute difference measures of PFT, adjusting for age and current smoking status.

Additional independent variables in the analyses of difference measures included mass median aerodynamic diameter of sampled aerosol, the arithmetic and geometric mean concentrations of particulate, and the percent of particulate <10 μm (in the respirable range). Significance of statistical tests was assumed to be .05 for all multivariate equations *a priori.*

Results

Table 1 provides summary demographic data for the 65 male and 29 female employees according to the three job exposure categories: wood dust, finishing, and unexposed. The mean age range of the groups was about 39 to 47 years; they were generally a group of veteran workers. In this sample, the men tended to be smokers and have about double the mean pack-years as the women; many female workers were nonsmokers. On the average, men have worked about twice as long in the furniture industry as women, bearing out remarks from women we interviewed who reported taking time out for child-rearing in their occupational careers. Regardless of gender, workers at this plant tended to remain in the job-exposure groups in which they were classified at the time of the study. As an example, the mean number of months employed in wood dust jobs compared with total length of employment in the furniture industry for male workers in the dust exposure group was 194.3 out of 222 months, and was 104.5 out of 108 months among female workers. Thus, among the group *currently* employed in wood dust-exposed jobs, 87% of the men's employment history in the furniture industry was in wood dust-exposed jobs, whereas 97% of the women's employment history was accounted for by employment in wood dust jobs. The other job-exposure groups had similar concordance. In this sample of relatively veteran and selected workers, employment in their current job-exposure is a strong predictor of their position through most of their careers.

The questionnaire was designed to detect respiratory symptoms such as cough, phlegm, shortness of breath, wheezing, and hay fever/rhinitis—many of the reported conditions associated with wood dust exposure. However, when we examined 19 symptoms, adjusting for age, sex, and pack-years using logistic regression, no significant associations were found for wood dust or finishing jobs or the interaction of smoking and either exposure, and cumulative length of employment (individual symptom responses are presented in ref. 17). We thought that affirmative responses to several chronic symptoms—wheezing most days *or* stopping for shortness of breath *or* nasal drainage for 3 months per year—may be related to wood dust exposure and might be a more utilitarian response in an exploratory study such as this. However, as shown in Table 2, this symptom complex was not significantly correlated with either wood dust or finishing jobs. In addition to the questions about hay fever/rhinitis (usual summer or winter stuffiness or nasal drainage 3 months/year), we also asked the following questions regarding acute responses: "While at work have you ever noticed that you had *frequent sneezing* or *eye irritation*?" As shown in Table 2, wood dust jobs were significantly correlated with both replies ($P = .030$ and $P = .049$) after controlling for age, sex, and pack-years. The prevalence odds ratio

TABLE 1
Descriptive Statistics on 65 Male and 29 Female Furniture Workers by Job-Exposure Group

	Wood Dust		Finishing		Unexposed	
	Men	Women	Men	Women	Men	Women
Number	44	11	9	14	12	4
Mean age, yr	47.2	41.3	39.4	42.9	42.2	44.5
Present smoker, %	54	45	67	21	67	25
Exsmokers, %	23	18	33	14	17	0
Nonsmokers, %	23	36	0	64	17	75
Mean pack-years	31.3	17.7	20.3	10.8	25.9	2.1
Mean No. mos. employed in:						
Furniture industry	222.3	107.6	171.2	125.1	211.8	102.8
Current job-exposure group	194.3	104.5	165.9	124.4	199.9	85.0

TABLE 2
Selected Results for Symptom Questionnaire Responses Using Logistic Regression

Question	Exposure	Confounders Adjusted	Prevalence Odds Ratio (~95% Confidence Intervals)	*P*
Positive response to either *wheezing most days* or *stopping for breath on level ground* or *rhinitis 3 months per year*	Wood dust jobs	Age, sex, smoking, hobbies	NS*	
	Finishing jobs		NS	
At work have you noticed you had *frequent sneezing*?	Wood dust jobs	Age, sex, and pack-years	4.05 (14.7–1.1)	.0302
At work have you noticed that you had *eye irritation*?	Wood dust jobs	Age, sex, and pack-years	4.02 (16.6–1.0)	.0488

* NS, not significant.

(POR) was 4.05 (approximately 95% confidence intervals [95% CI] = 1.1 to 14.7) for frequent sneezing; for eye irritation, wood dust jobs produced a POR of 4.02 (95% CI = 1.0 to 16.6).

Table 3 summarizes the results for baseline flows and volumes among white subjects only. The pulmonary function of four workers in the survey group was excluded because they were black or Asian and there were too few subjects for adequate analyses. The presumed covariates—age, sex, height, and pack-years—with some additional variables, explained from 50% to 70% of the variance. However, in all cases except peak flow, neither present employment nor cumulative person-months of exposure to wood dust or to finishing was significantly correlated. In the case of peak flow, cumulative months employed in wood dust jobs was a significant independent factor (P = .0345), after adjusting for sex, age, height, pack-years, and cigar smoking: the R^2 value rose to .566 from .542 with the addition of cumulative person-months in wood dust jobs. Except for FEF_{75}, we did not find significant interaction between smoking × drinking, or height × weight, or smoking × finish exposure, or smoking × wood dust exposure.[17]

The regression results for acute measures of the difference in pulmonary function over the work shift are displayed in Table 4. Our expectation was that if general exposure to wood dust, finishes, or particulate concen-

TABLE 3

Summary of Stepwise Regression Results for Baseline Flows and Volumes

Flow or Volume (Mean Value)	Confounders Adjusted (R^2 with Confounders)	β Values	$P > F$	Significant Exposure Variables ($P > F$)
FEV_1* (3.25 L)	Intercept	−0.500		None
	Age	−0.033	.0001	
	Sex	−0.679	.0004	
	Pack-years	−0.011	.0002	
	Height	0.031	.0016	
	(R^2 = .646)			
FVC (4.28 L)	Intercept	−3.938		None
	Age	−0.019	.0001	
	Sex	−0.556	.0043	
	Pack-years	−0.008	.0112	
	Height	0.057	.0001	
	Drinking	0.344	.0110	
	Prior illness	−0.559	.0022	
	(R^2 = .701)			
Peak flow (7.49 L)	Intercept	8.895		Cumulative months in wood dust jobs; β = −0.002 (0.0345)
	Age	−0.041	.0049	
	Sex	−2.437	.0001	
	Pack-years	−0.026	.0004	
	Height	0.026	.2270	
	Cigar smoking	−2.016	.0187	
	(R^2 = .542)			
FEF_{50} (3.95 L/sec)	Intercept	11.705		None
	Age	−0.053	.0001	
	Sex	−1.445	.0005	
	Pack-years	−0.026	.0001	
	Height	−0.016	.4371	
	Past chest conditions	−0.860	.0054	
	(R^2 = .515)			
FEF_{75} (1.35 L/sec)	Intercept	2.593		None
	Age	−0.037	.0001	
	Sex	−0.648	.0015	
	Pack-years	−0.006	.0702	
	Height	−0.014	.2291	
	Height × weight	<−0.001	.0189	
	Smoking × drinking	−0.477	.0012	
	(R^2 = .556)			
FEV_1/FVC (75.5%)	Intercept	1.659		None
	Age	−0.003	.0001	
	Sex	−0.043	.1350	
	Pack-years	−0.002	.0003	
	Height	−0.004	.0140	
	Past chest conditions	−0.082	.0002	
	(R^2 = .500)			

* The abbreviations used are: FEV_1, forced expiratory volume in 1 sec; FVC, forced vital capacity; FEF_{50}, 50% of forced expiratory flow; FEF_{75}, 75% of forced expiratory flow.

TABLE 4

Summary of Stepwise Regression Results for Acute Changes in Pulmonary Function, Adjusting for Age and Average Daily Smoking Habit (at a Minimum)

Difference Measure (Mean of Baseline Minus End of Shift)	Confounding Variables (R^2 Level Including Significant Variable)	β Values	$P > F$	Significant Exposure Variables ($P > F$)
Change in FEV_1* (−0.052 L)	Intercept	−0.054		Finishing jobs
	Age	0.001	.0254	$\beta = -0.0525$
	Average smoked per day	<0.001	.6890	(0.0451)
	($R^2 = .041$)			Wood dust jobs
				$\beta = -0.0443$
				(0.0567)
Change in FVC (0.02 L)	Intercept	−0.012		Finishing jobs
	Age	0.001	.5069	$\beta = -0.0351$
	Average smoked per day	−0.001	.4322	(0.0203)
	Mass median diameter	−0.013	.1212	
	Geometric mean	0.088	.0547	
	($R^2 = .081$)			
Change in peak flow (−0.07 L)	Intercept	−1.754		Fraction <10 μm
	Age	0.010	.0330	$\beta = 0.018$
	Average smoked per day	−0.005	.3202	(0.0272)
	Mean concentration	0.195	.0626	
	($R^2 = .108$)			
Change in FEF_{50} (−0.14 L/sec)	Intercept	−0.148		Wood dust jobs
	Age	0.002	.5968	$\beta = -0.078$
	Average smoked per day	−0.004	.3142	(0.0534)
	($R^2 = .024$)			
Change in FEF_{75} (0.10 L/sec)	Intercept	−0.271		Finishing jobs
	Age	0.003	.1410	$\beta = -0.085$
	Average smoked per day	0.004	.1322	(0.0253)
	($R^2 = .073$)			

* Abbreviations are as in Table 3.

trations had an acute effect, difference measures could detect them. Employment in wood dust-exposed jobs shows a borderline association ($P = .0567$) with change in FEV_1; the β coefficient, however, is negative. Although current employment in finishing jobs showed significant P values for the difference in FEV_1, FVC, and FEF_{75}, only difference in FVC is logically correlated with finishing exposure. That is because for small mean *declines* in FEV_1 and FEF_{75}, the β coefficient for current employment in finishing is *negative*. By contrast, for a slight mean *improvement* in difference in FVC (after adjusting for age, daily smoking, mass median particulate diameter, and geometric mean of the particulate), finishing has a *negative* β. The fraction of particulate <10 μm correlates significantly ($P = .0272$) with a change in peak flow over the shift after inclusion of age, average smoking level, and mean dust concentration in the regression equation. However, note that the R^2 values for these dependent variables are 10% or less, thus indicating that the associations, although significant statistically, are minimal. It is also worth noting that neither measures of particulate concentrations (median particle size, and arithmetic and geometric mean concentrations) nor interactive variables of smoking and exposure evidence any significant correlations.

Discussion

Although we found some acute symptoms (frequent sneezing and eye irritation showed PORs of 4.0) associated with hardwood dust exposure, unlike Andersen et al,[3] no precursor symptoms of nasal cancer (such as chronic rhinitis or nasal blockage for 3 months) were observed. The positive findings for frequent sneezing and eye irritation tend to confirm management's anecdotal remarks that some employees had asthma-like reactions when working with andiroba, although it is not possible to specify which wood is the primary reactant. In support of Al Zuhair et al[10] and Beckman et al,[23] we found no association between chronic symptom responses indicative of bronchitis, asthma, or rhinitis and furniture manufacturing. The lack of chronic symptoms in this group of veteran furniture workers likely reflects the two-way selection among current workers. First, these study subjects selected themselves by deciding to remain furniture workers and to tolerate their working environment until this point in their careers. Second, ex-workers who could not physiologically tolerate jobs in this plant (or who left for other reasons not related to health) or who may be disabled by dust or by finish exposures have been selected out of this sample, and their symptoms and PFT are not reflected in these findings. The lack of association may also be a reflection of the sample size; the power of this study to detect a doubling of symptom risk comparing wood dust-exposed workers to those unexposed to wood dust is only 55% given $\alpha = 0.05$, $\beta = 0.10$, and a background risk of 20% for respiratory symptoms.[24] However, with 50 workers exposed to wood dust, the study power is greater than 95% to detect a decline from normal to <80% of FEV_1.[24]

If we accept peak flow as a measure of large airways function, North Carolina hardwood furniture workers inhaling relatively large wood dust particles may be at risk of impaired peak flow. There are several reasons for caution in this interpretation. In the absence of correlations between wood dust exposure and bronchitis symptoms or impairment of flows and volumes such as FEV_1 and FVC, the association with baseline peak flow may be an artifact. Furthermore, the correlation may be a function of the large number of tests characteristic of an exploratory study and thus be a random event which is statistically significant once in 20 assessments by chance alone. By contrast, we are reassured that the known covariates of age, sex, height, and smoking explain the expected large amount of variance for all flows and volumes, so the correlation between peak flow and wood dust exposure is not likely to be explained by some unknown confounder. The significant correlation between change in peak flow over the shift and the fraction of particulate <10 μm is interesting in the light of the association between wood dust exposure and baseline peak flow. In fact, this suggests that belt and machine sanding and finishing jobs, which have the greatest fraction of dust in the respirable range, may be the work areas where future research should be focused. Furthermore, these findings should be examined in future studies to determine whether peak flow or FEV_1 (as reported by Al Zuhair et al[10]) correlates more highly with hardwood dust exposure.

There appears to be some association between employment in finishing jobs and acute change in FVC over the workshift, although the effects are not great. However, the data do not suggest any acute decline in respiratory function from current exposure to hardwood dusts, a finding that agrees with the work of Holness et al.[13] Furthermore, no correlation was observed between PFT differences and mass median aerodynamic diameter, the mean dust concentrations, or the percent of particulate <10 μm (with the exception of change in peak flow).

Conclusion

Since its inception in 1971 the Occupational Safety and Health Administration regulated wood dust as an inert or nuisance mineral dust (29 Code of Federal Regulations 1910.1000, Table Z-3) and the standard was an eight-hour time-weighted average concentration of 5 mg/m^3 for respirable dust and 15 mg/m^3 for total dust.[7] However, in two separate cases relating to citations for excess exposure to grain and wood dust heard before the Occupational Safety and Health Review Commission (OSHRC), the nuisance mineral dust standard was found to be inapplicable to organic dusts (Bunge Corporation: OSHRC docket nos. 77-1622, 78-838, and 78-2213; and Bemis Manufacturing Company: OSHRC docket no. 80-3443). Thus, wood dust is currently an unregulated occupational exposure. By contrast, in 1985, the American Conference of Governmental Industrial Hygienists (ACGIH) revised its recommended wood dust threshold limit value time-weighted average from 5 mg/m^3 to 1 mg/m^3 for hardwood and 5 mg/m^3 for nonallergenic softwood dusts, with a short-term (15-minute) exposure ceiling of 10 mg/m^3 for softwood only.[25] This guideline does not differentiate between total and respirable particulate.

Based on his work among Vermont furniture workers and other research demonstrating elevated risks for respiratory symptoms, nasal cancer, and impaired lung function, Whitehead[26] proposed a tightening of the health standard for occupational wood dust from 5 mg/m^3 to 2 mg/m^3 for all types of wood (based on the OSHA rule then in force). The highest mean concentration observed in this study was 4.97 mg/m^3 in the carving area, which at the time of the study was not connected to the plant's exhaust system. Most other dusty parts of the plant had a mean dust concentration of ~2 mg/m^3 or less.[17] We recognize that entry to the plant and access to its work force was partially a function of the low dust exposure there, but these results generally support the hardwood dust standard recommended by ACGIH.[25] In our opinion, there should be federal standards for control of wood dust exposure to protect against the risk of impaired pulmonary function or symptoms of respiratory disease.

In light of the contradictory findings in this and other studies, additional epidemiologic research, including longitudinal surveillance, needs to be undertaken relating respiratory effects (including nasal cytology exams) and hardwood dust exposure. Future studies should include exworkers and retirees as study subjects as well as current employees. Furthermore, given the potential for acute respiratory hazards from uncontrolled exposure to paints and varnishes in finishing jobs, additional clinical research in the furniture industry is warranted.

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Before You Sign That Lease

Office space priced per "rentable" square foot often turns out to be much more expensive than tenants expect because landlords may include space that tenants consider unusable. Normally, you'll be able to use only 75% to 90% of what you pay for. This difference, the loss factor, depends on three things: the physical configuration of your offices, your landlord's method of measuring rentable area, and, increasingly, your landlord's whim ... To protect yourself, you might hire an architect to measure the space you plan to lease and tell you whether the usable area will satisfy your business needs. The architect should use a generally accepted standard, like that adopted by the Building Owners and Managers Association, so that you can precisely compare one space with another.

* * * *

An operating expense clause lets your landlord recover normal out-of-pocket costs of running a building. That should be all he does. Operating expenses listed in your bill should correspond directly to benefits you gain under the lease, and they ought to meet an objective standard such as GAAP (Generally Accepted Accounting Principles), not conventions particular to your landlord.

—From "Before You Sign That Lease . . ." by Marisa Manley in *Harvard Business Review*, 1988;66(3):140.