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# Investigation and Control of Occupational Hazards Associated with the Use of Spirit Duplicators

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**A Health Hazard Evaluation was conducted by the National Institute for Occupational Safety and Health (NIOSH) to determine if vapors from duplicating fluid (99% methyl alcohol) used in direct-process spirit duplicating machines were causing adverse health effects among teacher aides, or had been responsible for the deaths of three former teacher aides. Death certificates and autopsy data were obtained and evaluated. A self-administered symptom questionnaire was distributed to current teacher aides (exposed group) and to a comparison group of teachers. Fifteen-minute breathing zone air samples for methyl alcohol vapor were collected at operator stations using an infrared gas analyzer. No information supported the claim that the three deaths were related to methyl alcohol exposure. Teacher aides reported significantly more blurred vision, headache, dizziness, and nausea than the comparison group. Concentrations of airborne methyl alcohol ranged from 365-3080 ppm; 15 of 21 measurements exceeded the NIOSH-recommended 15-minute exposure limit of 800 ppm. A mean 96% reduction in vapor concentration was accomplished using inexpensive enclosures and existing room exhaust systems.**

## Introduction

A common feature of small office environments, especially in the field of education, is the "spirit duplicator." A spirit duplicator is a machine that uses methyl alcohol, or "spirits," to reproduce printed material. The process consists of taking a master copy with a reverse image printed on it in an alcohol-soluble dye, and placing it on the drum of the duplicator. The paper to be printed is fed under and in contact with an alcohol-saturated wick, thus applying a thin layer of alcohol to the paper. As the paper comes in contact with the master copy, the alcohol dissolves a small portion of the dye and transfers the characteristically purple image to the finished sheet.

There are more than 300 000 teacher aides in the U.S.,<sup>(1)</sup> and many other persons who may be exposed to methyl alcohol while using spirit duplicators. Exposure can occur to the operator through inhalation of evaporated methyl alcohol, through skin absorption during handling of freshly duplicated paper, or otherwise, touching the methyl alcohol. Signs and symptoms of mild to moderate methyl alcohol toxicity include headaches, dizziness, nausea, temporary blurring of vision, and behavioral disturbances. Severe exposure can result in metabolic acidosis, cyanosis, blindness, coma, and death.<sup>(2,3)</sup>

## Background

In 1980, the National Institute for Occupational Safety and Health (NIOSH) conducted an investigation to determine if vapor from duplicator fluid (99% methyl alcohol), emitted during the use of spirit duplicators, was the cause of adverse health effects among teacher aides in a school district in the State of Washington, and if the deaths of three former aides were related to their exposure to duplication fluid.<sup>(4)</sup> The initial report to NIOSH indicated that all three deaths were due to "liver disease."

Three years prior to the NIOSH investigation, the school district had instituted what they referred to as a "purple curriculum," where each teacher made a packet of duplicated course materials for each student. These course materials were copied on spirit duplicators in the individual schools, primarily by teacher aides. The time spent working at or near the duplicating machines varied from as little as 1 hour a day, 1 day a week, to 8 hours a day, 5 days a week. Duplicators were located in rooms or areas that were either inadequately ventilated or not ventilated at all. After the institution of the "purple curriculum," aides experienced symptoms such as headaches, dizziness, and eye irritation when running the duplicators, and complained that the duplicating machines were not properly ventilated. The aides became especially concerned when three of their co-workers died within a 4-year period. This report presents the environmental and epidemiological results of the NIOSH investigation, and describes simple measures to control exposure to methyl alcohol vapor.

## Materials and Methods

### Environmental

Concentrations of methyl alcohol vapor were measured in the breathing zones of current teacher aides as they operated the duplicators and collated and stapled duplicated papers. Measurements were made on 21 of the 58 duplicators in 12 of the 18 schools in the school district. The sampling strategy included a cross-section of small and large rooms, rooms with windows that could be opened and those with non-operable windows, rooms with no windows, and rooms that had either none or some exhaust ventilation. The exhaust ventilation present included wall or ceiling fans directly behind or above the duplicators, and open duct ends above the duplicator or kitchen range-type hoods above the dupli-

**TABLE I**  
**Methyl Alcohol Air Concentrations<sup>A</sup> (ppm)**  
**in Spirit Duplicator Operators' Breathing Zone**

No Exhaust Ventilation	Existing Ventilation	Existing Ventilation plus Enclosure
1100	120	
1180	135	15
365	80	9
1365		
915		
1000		
435		
1275		
575	480	
1250	650	130
	120	35
	265	
	375	
1040		
500		
940		
3080	430	
1185	680	
1270	410	15
410		
970		
1290		
1440	1340	90
685		

**Evaluation Criteria for Methyl Alcohol:**

1. Short-term exposure level for any 15-minute period - 800 ppm (NIOSH recommended level)
2. Eight hour time-weighted average - 200 ppm (OSHA Permissible Exposure Limit)

<sup>A</sup>Concentrations listed represent 15-minute sampling periods.

NOTE: Room temperatures were not measured but were within the normal comfort range.

cators (Table I). The breathing-zone air concentrations were measured using a Wilks Miran 1A<sup>A</sup> gas analyzer. One 15-minute sample was collected under each operating condition. This sampling period was chosen because 1) the NIOSH-recommended standard is based on this sampling time; 2) it was difficult to characterize a typical 8-hour workday because individual aides worked as little as 1 hour a day, 1 day a week, to 8 hours a day, 5 days a week; and 3) it was more convenient to use short-term sampling and a direct-reading instrument to measure the effects of ventilation modifications. There was no attempt to compare duplicator brands because of the large variations in room configurations, the state of repair of the duplicators and the variation in operating parameters for each location and machine.

Utilizing principles of good local exhaust ventilation,<sup>(5)</sup> alternative hood designs were constructed from cardboard by the NIOSH investigators for six of the duplicators. Alterations included enclosure of the duplicator on the back, sides and top leaving adequate space in front to operate the duplicator. The enclosures were similar to those shown in Figures 1-3. The existing ventilation rates were not altered.

<sup>A</sup>Mention of a product name does not constitute an endorsement.

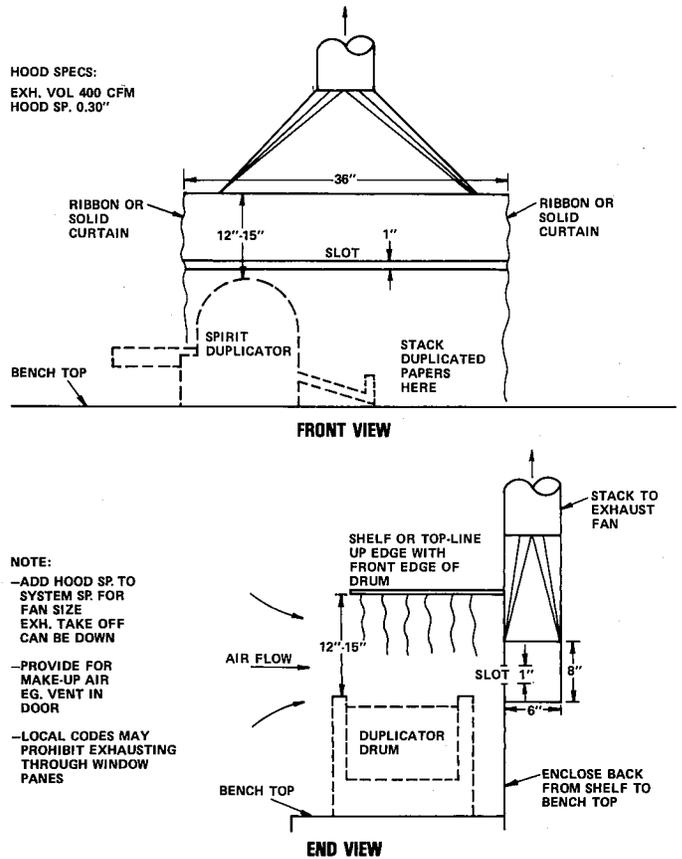


Figure 1 — Preferred method, good enclosure with slot exhaust.

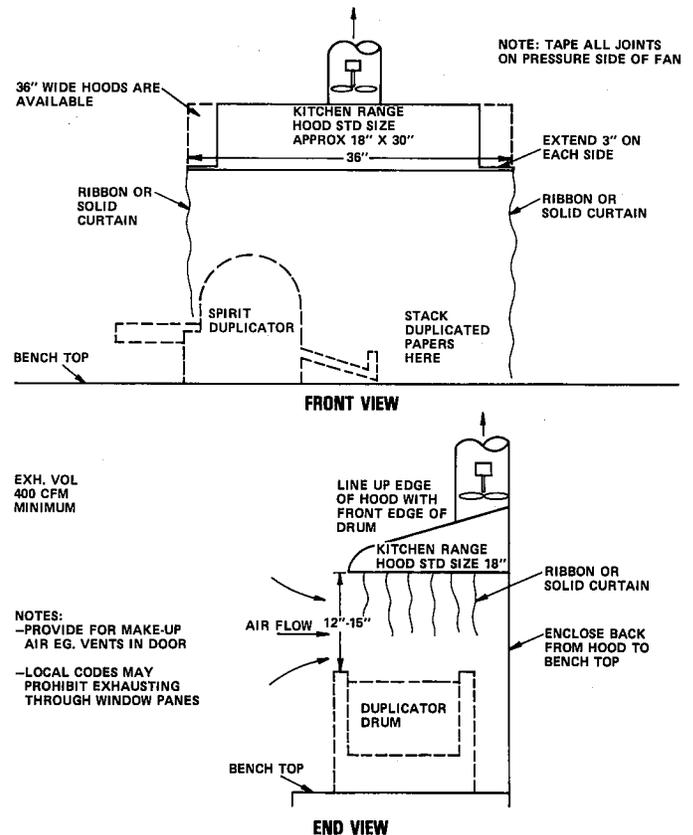


Figure 2 — Alternate method, kitchen range type hood with good enclosure.

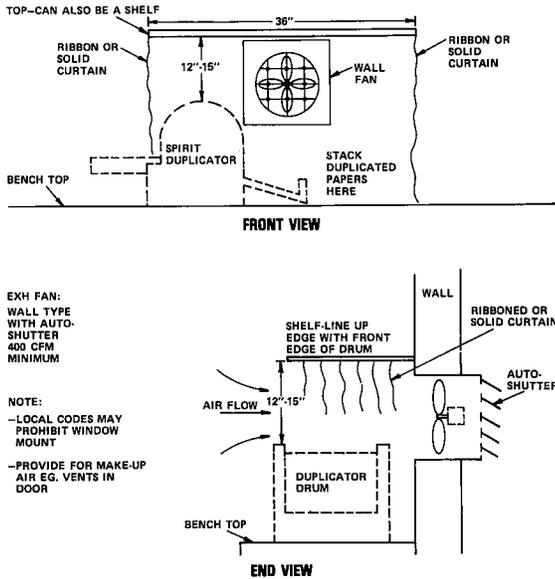


Figure 3 — Alternate method, wall fan with good enclosure.

Methyl alcohol concentrations were determined before and after the temporary modifications were made (Table I).

#### Medical

A self-administered questionnaire designed to elicit symptoms of methyl alcohol toxicity was given to the 84 current teacher aides, and to a comparison group of 302 (287 or 95% of whom responded) female teachers in the school district. Only female employees were included because all but one of the teacher aides were female.

Death certificates and autopsy data were obtained for the three deceased aides. This information was examined for common patterns and consistency with the known effects of methyl alcohol.

Efforts also were made to determine whether any other aides had died during the last 10 years. A list was obtained of all teacher aides who had ever worked in the school district. This list was sent to the State Department of Retirement Systems for information on whether any of these people had died, and, if so, the reported cause of death.

## Results

### Environmental

The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits for methyl alcohol is an 8-hour time-weighted average (TWA) of 200 ppm. The NIOSH-recommended standard includes this TWA level and a short-term ceiling level of 800 ppm over any 15-minute period. Twenty-one, 15-minute breathing-zone concentrations (shown in Table I), measured during the use of duplicators with no exhaust ventilation, ranged from 365 to 3080 ppm (mean concentration, 1060 ppm; median, 1040 ppm). Fifteen of these 21 measurements exceeded 800 ppm. Eleven assorted exhaust ventilation systems were available, which included wall fans, ceiling fans, and kitchen range hoods. These exhaust systems did not provide enclosures. With these systems turned on, the 15-minute concentrations ranged from 80 to 1340 ppm, with only one exceeding 800 ppm. When the six NIOSH fabricated enclosures were used with the existing exhaust systems, the 15-minute concentrations ranged from 9 to 130 ppm. These latter values represented a 90 to 99% reduction in exposures as compared to measurements made using duplicators with no exhaust systems, and a 71 to 96% reduction in the corresponding concentrations as measured in rooms with the existing exhaust systems in use (Table II). The aides' breathing-zone concentrations while collating and stapling papers, which had been duplicated up to 3 hours earlier, ranged from 180 to 875 ppm. Twenty-four hours after duplication the concentration was 190 ppm, and 48 hours after duplication concentration was still 35 ppm (Table III).

### Medical

Sixty-six of the 84 teacher aides (79%) completed questionnaires. Their responses were compared to a group of 66 teachers (already matched for sex) randomly selected from those who responded (Table IV). The mean age of the teachers was 37.5 years (range 24 to 59), while that of the aides was 39.8 years (range 24 to 60). A comparison of the prevalence of symptoms between the two groups, in the month prior to the investigation, revealed that the most significantly different symptom was blurred vision, which

**TABLE II**  
**Comparison of Effectiveness of Existing Ventilation Systems and NIOSH Fabricated Enclosures**

No Ventilation	Existing Ventilation		Existing Ventilation Plus Enclosure	
	ppm Methyl Alcohol	% Reduction	ppm Methyl Alcohol	% Reduction
-	120	-	35	-
365	80	78	9	98
1180	135	89	15	99
1250	650	48	130	90
1270	410	68	15	97
1440	1340	7	90	94
	Mean	58	Mean	96
	Median	68	Median	97
	Range	7-89	Range	90-99

**TABLE III**  
**Methyl Alcohol Breathing Zone Air Concentrations**  
**While Collating and Stapling Papers**

Time Between Duplication and Collation	15-Minute Average Concentration (ppm)
0-3 Hours	875
0-3 Hours	685
0-3 Hours	490
0-3 Hours	180
Approximately 24 Hours	190
Approximately 48 Hours	35

was reported by 15 (23%) of the aides vs. 1 (1.5%) of the teachers ( $p < 0.001$ ). Aides also reported more headaches, 34% compared to 18% for teachers ( $p < 0.05$ ), as well as more dizziness, 30% vs. 1.5% ( $p < 0.001$ ), nausea, 18% vs. 6% ( $p < 0.01$ ), and skin problems, 11% vs. 1% ( $p < 0.10$ ). Although these data were the result of self reporting, the two groups showed similar prevalences of symptoms unrelated to methyl alcohol toxicity such as: painful urination, 3% vs. 4.5%, diarrhea, 0% vs. 0%, poor appetite, 1.5% vs. 0%, and jaundice, 0% vs. 0%. Based on symptoms reported in the literature and chosen by a NIOSH physician (not associated with the study), a case of methyl alcohol toxicity was defined by any of the following four symptom aggregations: 1) visual changes or blurred visions; 2) one acute symptom (headache, dizziness, numbness, giddiness, nausea, or vomiting) and one chronic symptom (unusually tired, muscle weakness, trouble sleeping, irritability, or poor memory); 3) two acute symptoms; or 4) three chronic symptoms. Using these criteria,

**TABLE IV**  
**Prevalence<sup>A</sup> of Symptoms Among**  
**Teachers Aides and Teachers**

Symptoms	Teachers n=66	Aides n=66
Headache	18.1 <sup>B</sup>	34.8 <sup>B</sup>
Dizzy/lightheaded	1.5 <sup>B</sup>	30.3 <sup>B</sup>
Blurred vision	1.5 <sup>B</sup>	22.7 <sup>B</sup>
Nausea/upset stomach	6.0 <sup>B</sup>	18.0 <sup>B</sup>
Trouble sleeping	10.6	13.6
Unusually tired	24.2	24.2
Irritable	10.6	12.1
Giddiness	0	1.5
Poor memory/confusion	1.5	6.0
Muscle weakness	1.5	3.0
Dry/sore throat	16.6	16.6
Burning/itching/tearing of the eyes	12.1	25.7
Trouble with or changes in vision	10.6	15.7
Chills	9.0	12.1
Poor appetite	1.5	0
Unusual weight loss	0	1.5
Vomiting	0	0
Diarrhea	0	0
Painful urination	4.5	3.0
Skin problems	1.5	10.6
Jaundice	0	0
Numbness in hands and arms	6.0	7.5
Other	13.6	19.6

<sup>A</sup>Percent experiencing symptoms during month prior to investigation.

<sup>B</sup> $p < 0.05$ , Chi-Square.

ria, 45% of the aides were classified as cases, compared to 24% of the teachers. This association was significant at  $p < 0.025$  ( $X^2 = 6.6$ ). When stratified by 5-year age groups, the prevalence of cases was greater for aides in all age groups except 41 to 45. The Mantel-Haenszel chi-square test for the significance of the overall degree of association based on the various age strata was significant at  $p < 0.05$ .

The case attack rate also was analyzed by the amount of time per week spent at duplicating machines (Figure 4). This revealed that as the percent of time increased, so did the proportion of the group classified as cases. Aides who spent an average of 85% of their time (based on a 40-hour week) at or near a duplicating machine had a 50% attack rate.

A review of the death certificates or autopsy information of the three deceased aides showed three distinct causes of death: cancer of the ovary; oat cell carcinoma of the lung (metastatic to the liver); acute pancreatic necrosis and severe post necrotic cirrhosis of the liver, presumably secondary to hepatitis. These diagnoses showed no consistent pattern suggestive of a common cause. Upon searching records of the retirement system, no further deaths of aides were found. Fifty former members, however, had terminated their participation in the retirement system, and it was not known if they were still alive.

### Discussion

The primary concern that prompted the investigation was that three teacher aides had died from "liver disease." This common pattern was not substantiated, and in fact, the deaths were due to three different causes. These data do not resolve the question of whether methyl alcohol, like ethyl alcohol, is hepatotoxic in humans. Methyl alcohol is toxic when inhaled or ingested in large quantities,<sup>(6)</sup> but is not known to be a human liver toxin. However, there have been no long-term epidemiologic studies of liver function in chronic, low-level occupational exposures to methyl alcohol. Animal toxicology studies from the early 1900's revealed deterioration of liver tissue, proceeding in the more severe cases to focal necrosis.<sup>(7-9)</sup> The data from those investigations were, however, presented summarily and not in sufficient

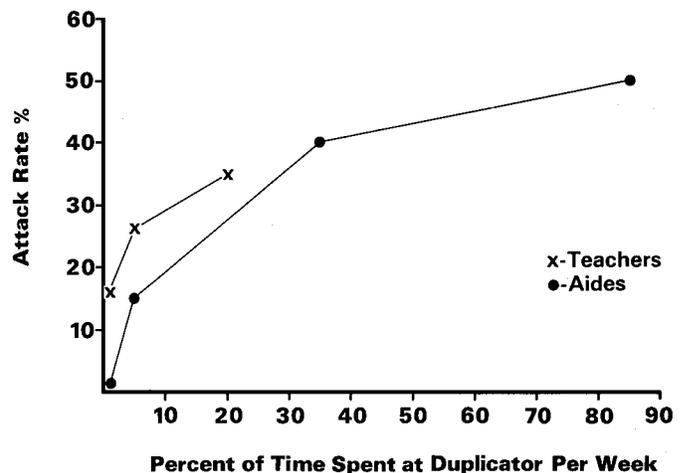


Figure 4 — Relationship between percent of time spent at spirit duplicating machine and attack rates.

detail for critical evaluation. Additionally, primates and non-primates metabolize methyl alcohol differently, and the importance of this inter-species difference must be considered when evaluating toxicity data from lower animals.<sup>(9)</sup> There have been autopsy reports of pancreatic necrosis in humans after ingestion of methyl alcohol. As with liver toxicity, the pancreatic pathology in humans is not specific, and chronic ethanol intake is usually an important confounding and likely causative factor.

The present study identified a potential health hazard associated with the use of "spirit duplicators." An earlier study of a spirit duplicator use reported headaches associated with methyl alcohol concentrations ranging from 200 to 375 ppm.<sup>(10)</sup> The present study detected much higher levels of methyl alcohol vapor ranging from 365 to 3080 ppm, and in addition to headaches, found other, more ominous symptoms, such as blurred vision, consistent with methyl alcohol toxicity. The data were gathered via self-administered questionnaires during a period when emotion was high and discussion of the issue extensive, raising the possibility that prevalence of reported symptoms may have increased as a result of the heightened awareness. Both groups, however, responded similarly to questions involving symptoms not associated with methyl alcohol exposure, indicating that symptoms were not reported indiscriminately. Further, the positive response rate of the teachers may have been augmented since some of them worked with the duplicators. The prevalence of symptoms in both groups, thus, may have been elevated slightly, but this did not appear to alter the relative differences between the two groups. This study demonstrated how even make-shift ventilation systems could reduce the concentration of methyl alcohol vapor an average of 58%, and how, with utilization of good ventilation system design, a much greater (average, 96%) reduction could be achieved. Figures 1-3 illustrate the types of local exhaust ventilation found to be effective for use with spirit duplicators.

### Recommendation

The following recommendations were offered to the school district to control and/or prevent exposure to methyl alco-

hol vapors from "spirit duplicators": 1) provide local exhaust ventilation with good enclosures, unless measured air concentrations indicate that existing ventilation is adequate (see Figures 1-3); 2) prevent re-entry of exhausted vapors through nearby open windows or doors; 3) allow duplicated papers to air dry for at least 24 hours before collating and stapling; and 4) do not wash hands with duplicator fluids; use soap and water or waterless hand cleaner instead.

### References

1. Based on 1970 Census Figures. Bureau of the Census. Washington, DC (1970).
2. **Dreisbach, R.H.:** Handbook of Poisoning: Prevention, Diagnosis and Treatment. 10th Ed. p. 161, Lange Medical Publications, Los Altos (1980).
3. **National Institute for Occupational Safety and Health (NIOSH):** Criteria for a Recommended Standard . . . Occupational Exposure to Methyl Alcohol. pp. 19-75. HEW Publication No. 76-48 (1976).
4. **National Institute for Occupational Safety and Health (NIOSH):** Everett School District. Hazard Evaluation and Technical Assistance Report. TA 80-32. Cincinnati, OH. (1980).
5. **American Conference of Governmental Industrial Hygienists, Committee on Industrial Ventilation:** Industrial Ventilation — A Manual of Recommended Practice, Ed. 16, (1980).
6. **Bennett, I.L., Jr., F.H. Gary, G.L. Mitchell, Jr., and M.W. Cooper:** Acute Methyl Alcohol Poisoning — A Review Based on Experiences in an Outbreak of 323 Cases. *Medicine* 32:431-463 (1953).
7. **Tyson, H.H. and M.J. Schoenberg:** Experimental Researches in Methyl Alcohol Inhalation. *JAMA* 63:915-925 (1914).
8. **Scott, E., M.K. Helz, and C.P. McCord:** Histopathology of Methyl Alcohol Poisoning. *Am. J. Clin. Pathol.* 3:311-319 (1933).
9. **Patty, F.A., ed.:** Industrial Hygiene and Toxicology, 2nd Ed., p. 1415. Interscience Publishers, New York (1962).
10. **Kingsley, W.H. and F.G. Hirsch:** Toxicologic Considerations in Direct Process Spirit Duplicating Machines. *Compen. Med.* 40:7-8 (1954-55).  
26 April 1982; Revised 5 July 1983