

Health Hazard Evaluation Report

HETA 82-272-1276
BOEING VERTOL COMPANY
PHILADELPHIA, PENNSYLVANIA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

HETA 82-272-1276
MARCH 1983
BOEING VERTOL COMPANY
PHILADELPHIA, PENNSYLVANIA

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I. SUMMARY

On April 15, 1982, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Boeing Vertol Company to evaluate reported employee health complaints in the Purchased Parts Stores (PPS) and Packaging areas of Building 3-25, including anxiety, nausea, eye strain and headache. These were thought possibly to be related to working under high pressure sodium vapor (HPSV) lamps and working with storage boxes dipped in sulfur.

NIOSH investigators conducted an initial medical and environmental survey in May 1982 and a follow-up survey in July 1982. Air samples were collected for evaluation of exposures to sulfates, sulfites and sulfur dioxide. A calibrated photometer was used to measure the workplace illumination in units of lux. Self-administered questionnaires were completed by 37 employees in the Packaging Area who worked under HPSV lamps; by 26 employees in PPS who worked under HPSV lamps and with sulfur boxes; and by 19 employees in the Pattern Shop, who worked in a different building which did not have either HPSV lamps or sulfur boxes. To further assess possible color distortion, NIOSH investigators administered the Farnsworth-Munsell 100-Hue Test to 15 employees in Building 3-25.

Environmental sampling demonstrated non-detectable levels of sulfite; sulfate levels ranged from 9-14 ug/M³ and sulfur dioxide levels ranged from 7-10 ug/M³ - NIOSH recommended standard 1300 ug/M³; OSHA standard 13,000 ug/M³). The illumination levels in some parts of the building were far less than optimal. There was much concern over glare, particularly in relation to the video display terminals.

The prevalence of reported symptoms of eye fatigue (52% vs 30%) and loss of smell (30% vs 0%) was significantly greater in PPS (where sulfur boxes and lower illumination were present) than in packaging (where boxes were absent and higher illumination levels existed). The prevalence of reported blurred vision (59% vs 30%) and of eye irritation (43% vs 0%) was significantly greater in packaging (HPSV lamps present) than in pattern-makers (HPSV lamps absent). Results of the 100 Hue Test were consistent with a slight impairment, under HPSV lamps, of discrimination of certain colors.

Although no serious adverse health effects were noted, symptoms related to the eyes and minor abnormalities of color discrimination, possibly related to HPSV lamps and exposure to sulfur containers were detected. Recommendations to improve the lighting situation are presented in Section VIII.

KEYWORDS: SIC 3721 (Aircraft), High Pressure Sodium Vapor Lamps.

INTRODUCTION

On April 15, 1982, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Boeing Vertol Company to evaluate reported employee health complaints in the Purchase Parts Stores (PPS) and Packaging Areas of Building 3-25. The request identified a number of employee symptoms: depression, anxiety and crying episodes in PPS, apparently attributed to storage boxes dipped in sulfur for fire retardation and stiffening; and nausea, eye strain and headache in both PPS and Packaging, attributed to working under high pressure sodium vapor (HPSV) lamps.

NIOSH conducted an initial medical and environmental survey in late May 1982 and a follow-up survey in July 1982.

III. BACKGROUND

Boeing Vertol Company is engaged in the design and manufacture of helicopters. It employs approximately 4500 people. In December 1981, a new building, 3-25, was opened by the company. It houses a number of storage areas including PPS and packaging departments (Figure 1), which had been previously scattered in various other buildings. The distribution of lighting fixtures in these areas is shown in Figure 2. High pressure General Electric 400-watt sodium vapor lamps ("Lucalox") are the major sources of illumination; there are also a few fluorescent lamp fixtures and two sunlight portals. All HPSV lamps were mounted in standard reflectors having some degree of diffusing capability (i.e. lamps did not present themselves as point sources). The spectral emission of these lamps, according to the manufacturer's specification, is shown in Figure 3. The spectrum contains wavelengths throughout the visible radiation region with peak emissions occurring in the wavelength region from 575 to 610 nanometers (nm). A negligible amount of ultraviolet radiation is produced by these lamps.

At about the same time that building 3-25 opened, the company introduced new storage boxes (Convoy, Incorporated, Canton, Ohio) for use in PPS. These consisted of corrugated cardboard that had been immersed by the manufacturer in 99.9% pure molten sulfur for fire retardation and stiffening. According to the box manufacturer, in the absence of combustion, it was believed that only sulfur dust would come off the boxes.

IV. MATERIALS AND METHODS

A. Environmental: Industrial Hygiene

Four employee exposures and two general air samples in Building 3-25, Purchased Parts Storage, were evaluated for sulfates, sulfites and sulfur dioxide on June 3, 1982. The air samples were collected on cellulose filters impregnated with potassium hydroxide using sampling pumps operating at approximately 1.5 liters per minute. These samples were subsequently analyzed by NIOSH Method P&CAM No. 268.21

B. Environmental: Optical Radiation

Since the spectral content of HPSV lamps is well known, it was necessary only to perform illumination measurements for this study. A calibrated Photo-Research System 500 Photometer was used to measure the workplace illuminance in units of lux. The photometer was held about 5.2 meters below the light fixtures which is approximately the position where workers would locate. The survey was performed in Building 3-25 during the afternoon of July 1, 1982 in those locations where workers reported symptoms. At least two measurements were made at each location, and the highest result was recorded.

C. Medical/epidemiology

On the initial survey, the NIOSH investigators gave self-administered questionnaires to all available day shift employees in PPS and packaging. The questionnaire addressed a number of eye/visual symptoms as well as taste, smell, mood and other bodily functions. The four eye-related questions asked are displayed in Appendix I. As a comparison group (i.e. not working under HPSV lamps), all employees in the Pattern Shop (Building 3-56) who were concurrently being assessed as part of HETA 82-146, which did not involve eye symptoms or neurotoxins, completed the same questionnaire. The questionnaire addressed two time periods: "right now or in the past 30 minutes" and "in the past week but not counting today". The responses for the latter period were not properly completed for all respondents. It was possible that the instructions were not completely understood by all those filling out the questionnaire. Thus, only responses for the immediate time frame were analyzed.

To further assess the problem, and because of reports of color distortion observed in the few previous investigations of indoor use of HPS lamps, the Farnsworth-Munsell 100-Hue Test²² was administered on the return visit to 15 individuals. This test offers a simple method for testing color discrimination; the object is to arrange a series of colored caps in order according to color. With the assistance of a consultant psychologist specializing in visual

physiology, the test was administered to 15 employees and was scored by computer at the Wills Eye Hospital, Philadelphia, Pennsylvania. Changes in color perception produced by HPS light were sought by repeating the 100-Hue procedure once with a standard light source and again at the work area under HPS light. To control for any learning effect, NIOSH investigators alternated the light source under which the subjects performed the test initially.

V. EVALUATION CRITERIA

1. Sulfur dust/ sulfur dioxide

Sulfur dust is irritating to the mucous membranes, particularly the eyes¹⁻², and can be associated with lacrimation (excessive tear production), photophobia (discomfort caused by ordinary light levels), conjunctivitis (inflammation of the surface of the eye) and blepharoconjunctivitis (conjunctivitis with involvement of the eyelids). In fact, eye irritation in humans associated with a concentration of 8 parts per million (ppm) of sulfur has been reported.³ Associated with airborne sulfur dust is the danger of release of SO₂ leading to the inhalation of irritant vapors.¹

Sulfur dioxide is an irritant to the mucous membranes of the eye and respiratory tract. It has a pungent smell detectable at 3 ppm. In low concentrations it can also cause lacrimation, sneezing and coughing.⁴ The irritant effects of SO₂ are caused by formation of sulfurous acid (sulfites) on contact with moist membranes.^{5,6} With continuous exposure, upper respiratory disease, partial loss of taste and partial loss of smell can occur.^{7,8} Sulfuric acid appears, on a chronic basis, to be a more potent irritant than sulfur dioxide.⁴ However the sulfate ion per se is not irritant, and the sulfates vary widely in irritant potency depending on the cation found with the sulfate radical (anion).⁴

There are no specific standards for sulfites or sulfates, except for sulfuric acid (1 mg/M³ or 1000 ug/M³ as a time-weighted average). The OSHA standard for sulfur dioxide is 13,000 ug/M³ (5 parts per million) as an 8-hour time-weighted average, while the NIOSH recommended standard is 1,300 ug/M³ (0.5 ppm).^{5,20}

2. Health effects of sodium vapor lighting

There are a few documented reports of complaints, generally involving color changes and visual task distortions, associated with working under HPSV lights. Reports from schools⁹ and industries¹⁰⁻¹¹ emphasize eye strain, eye pain, headaches, glare, and color changes. It has been noted that in industrial situations where HPSV lamps are used for general illumination purposes, workers who are protanopes (redblind) may be severely handicapped due to the lack of color perception. A recent study reported a slight increase in body and adrenal gland weight in Sprague-Dawley female rats exposed to HPSV lamps.^{12,13,14} The study was reconfirmed recently at the National Institute of Environmental Health Sciences (NIEHS)¹⁵ using the same protocol. The NIEHS study showed that rats born and reared under HPSV lamps have increased adrenal gland weight when compared to rats reared under daylight-simulating fluorescent lights. The authors concluded that the differences in adrenal weights were statistically significant and might be due to the spectral difference between the two sources. They were not able to show statistically significant differences between groups on stress or behavioral tests. A recent NIOSH report evaluating HPSV lamps at a large industrial plant concluded that no health effects could be directly attributed to the lamps.¹¹ However, it was pointed out that the guideline values for optical radiation have been based on skin and ocular effects and not behavioral effects.

Few studies have been performed to assess the acceptability of HPS illumination. One study compared the acceptability of high intensity discharge sources for offices.¹⁷ Fluorescent, metal halide, high-pressure sodium and metal halide high-pressure sodium sources were compared. No significant differences were found among the four lighting sources, by analysis of variance for time and for omission errors during a visual acuity task. For the color discrimination task, again no significant differences were observed. An Italian study¹⁶ reported that under illumination produced by a high-pressure sodium lamp as compared to that under CW (cool white) light, color discrimination was found to be impaired, as assessed with the 100-Hue Test. A more recent study¹⁸ found that mean performance of a simulated clerical task (multiple refocus task) in an office environment was significantly poorer under HPS light than under CW fluorescent light. This finding was independent of age and refractive state. It was felt that HPS light reduced many subjects' abilities to perform the task and that it does affect visual performance.

VI. RESULTS

A. Environmental: Industrial Hygiene

The environmental results are summarized in Table I. Sulfate exposures ranged from 10 to 14 micrograms per cubic meter of air. All sulfite air samples collected were below the limit of detection, which was 4 micrograms per sample. Air levels of sulfur dioxide ranged from 7 to 10 ug/M³. This is well below both the OSHA standard and the NIOSH recommended standard.

B. Environmental: Physical Agents

As can be seen in Table II, the illumination in the Packaging Area is consistently higher than in the Purchased Parts Storage area. Since the fixtures are mounted at the same height in both areas, the illumination difference is accounted for by a greater density of lamps in the Packaging Area. The nature of the work in the Packaging Area demands a higher visual requirement and consequently the illumination is more critical. Table II also shows that certain places within the PPS area do not have sufficient illumination for satisfactory working conditions. This is most notable within the storage work zone. Finally, it is interesting to note from Table II that the illumination in the two areas with fluorescent lamps is much higher than that in areas with only HPSV lamps. In the portion of the Packaging Area that used video display terminals (VDT) and microfilm readers, the glare reflected by the VDT screen face was very annoying to workers.

C. Medical/Epidemiology

1. Demographic data

Demographic data for the non-supervisory employees in the three departments from which subjects were seen (Purchase Parts Stores, Packaging and Pattern Shop) are shown in Table III. The ages were comparable; the packaging employees had a much greater proportion of females.

2. Sulfur-coated boxes/Illumination levels

NIOSH investigators noticed a sulfur-like odor when close to the boxes. The prevalence of positive responses was compared between storekeepers in PPS (sulfur boxes in work area) and packagers (no sulfur boxes in work area) (Table IV). Both groups worked under HPS lamps. The prevalence of reported

"hot, tired, aching eyes", by 16(62%); eye fatigue by 16(62%); and loss of smell by 7(30%) of 26 employees was significantly greater in PPS than in the Packaging Area [11(30%), 11(30%) and 0(0%) of 37, respectively]. The prevalence of reported "eye irritation" and loss of taste was also greater, but this difference was of borderline statistical significance. These symptoms are compatible with exposure to sulfur and sulfur dioxide as well as being associated with the low illumination levels noted above.

3. High-pressure sodium lamps

Because the employees in PPS had the possible confounding exposure to sulfur boxes, differences in symptoms attributable to HPSV lighting were sought between packers (who worked under HPSV lights but not with sulfur boxes) and pattern-makers in Building 3-56 who had neither exposure. Table V shows these comparisons. The prevalence of symptoms of blurred vision [11(30%) of 37] and of eye irritation [16(43%)] was significantly greater in the packers, who worked under HPSV lamps than in the pattern-makers, who did not [1(5%), and 0(0%) of 19, respectively]. There was a highly significant difference in the frequency of reporting of two or more of the four eye symptoms (Appendix A) between the packers (14 of 37) and pattern-makers (none of 19), as shown in Table VI.

The test results of the Farnsworth-Munsell 100-Hue Test were reported as a numerical error score, shown in Table VII. The square root-transformed scores distribute normally (19); differences were analyzed for those individuals with no evidence of defective color vision. Overall, color discrimination was significantly impaired ($p < 0.05$) under HPSV light in comparison with a standard light source. When examining subgroups by light source used for initial test, a significant difference was noted only for those performing the test under HPSV light first.

VII. DISCUSSION AND CONCLUSIONS

The higher prevalence of reported symptoms related to eyes, loss of taste and loss of smell in PPS, the detectable sulfur dioxide on environmental sampling and the odor noted in PPS are all compatible with exposure to sulfur dust and sulfur dioxide. The eye symptoms are also compatible with the lower illumination in PPS.

Comparing the packers and pattern-makers, the prevalence of reported symptoms of eye blurring and of eye irritation was significantly greater in the former group, who worked under HPSV lamps. These results may have been biased somewhat toward finding no difference because individuals in the (control) pattern-maker group were themselves exposed to potentially irritating substances, including epoxy resins. These complaints from workers in the packaging area

were very similar to studies concerning HPSV lamps reported in the literature. This is not surprising due to the high visual demand of workers in this area and the newness of the installation of these lamps (i.e. less than 6 months). Many of the workers had attempted to reduce the glare and overall scene brightness by the use of sunglasses.

Color distortion, which has also previously been noted in the literature, was reported in this study more frequently, but not significantly so. These symptoms were examined further in this survey with the administration of the 100-Hue Test. This testing revealed results that were consistent with a slight impairment, under HPSV light, of discrimination of certain colors. This is consistent with findings in the literature, but it is unclear whether this is related to the other symptoms reported by packaging workers.

VIII. RECOMMENDATIONS

1. The amount of sulfur dust generated by the boxes is likely to decrease with time. However, this type of box should be avoided in the future.
2. In the packaging area, attention should be given to rearranging tables to positions closer to fluorescent lamps, using indirect ceiling lighting, installing greater diffusion capability on lamp fixtures, reducing lamp wattage, removing or not using some HPSV lamps, increasing use of sunlight portals, and mixing different lamp types. Incorporation of some or all of these suggestions would help to effect a more pleasing visual working condition.
3. The VDT and readers could be re-arranged so that glare onto the screen is minimized. Anti-glare screens or screen shields could be installed.
4. Additional lamp fixtures should be installed in those parts of the storage area where illumination is excessively below any recommended standard (i.e. 0-10 lux).

While these recommendations are made to improve lighting factors, it must be realized that workers may not like, or may not be accustomed to the type of light produced by HPSV lamps. Although the color produced by the HPSV lamp may be annoying, there is no evidence that this light type is hazardous to one's health.

IX. REFERENCES

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XI. DISTRIBUTION

1. Boeing Vertol Company, Philadelphia, Pennsylvania
2. Local 1069, UAW
3. OSHA, Region III
4. NIOSH, Region III

TABLE I

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

October 1982

Building 3-25 (Purchased Parts Storage)
Results of Sampling for Sulfate, Sulfite, Sulfur Dioxide (TWA)*

Location	Sample #	Time	Sulfite	Sulfate	Sulfur Dioxide	Remarks
Row 7-8	1	7:45-15:15	4**	14	10	General Air
Foreman's desk	2	7:40-15:15	4	13	9	General Air
Employee	3	7:30-14:51	4	12	8	O.E.***
Employee	4	7:48-15:16	4	11	8	O.E.
Employee	5	7:26-15:14	4	9	7	O.E.
Employee	6	7:34-15:15	4	12	8	O.E.
Row 3-4	7	7:56-15:15	4	13	9	General Air

*Denotes micrograms per cubic meter of air sampled.

**Denotes less than 4 micrograms, limit of detection for each filter.

***Denotes operator's exposure.

Criteria (micrograms per cubic meter)

<u>Substance</u>	<u>OSHA</u>	<u>NIOSH</u>
Sulfur Dioxide	13,000	1,300

TABLE II

Boeing-Vertol Company
Philadelphia, Pennsylvania
Building 3-25
HETA 82-272

October 1982

Illumination measured at a 17' detector to lamp distance

Area	Lamp Type	Illuminance (lx)
Purchased parts stores		
a) front storage racks (1 lamp)	HPSV	400
b) mid-point of 4 lamp cluster	HPSV	360
c) entrance of storage rack (3 different locations)	HPSV	10-170
d) Aisleway(s) of storage rack (7 different locations)	HPSV	0-130
e) open area-front of storage rack	HPSV	334
f) desk area directly under lighting	Fluorescent	1900
g) 5' from desk area not directly under fluorescent lighting	Fluorescent	1700
Packaging		
a) directly under HPSV lamps (5 locations)	HPSV	600-840
b) desk areas under fluorescent lamps (3 locations)	Fluorescent	1370-1410
c) near desk areas	HPSV	660-770
d) between rows of workers (2 locations)	HPSV	600-610
e) mid-point of 4 lamp cluster	HPSV	900
f) in lower light grid directly under HPSV (lamp spacing similar to purchased parts storage - 2 locations)	HPSV	350-360

From the IES (Illumination Engineering Society) Lighting Handbook, an exposure guideline for illuminance is 500 lux.

TABLE III

Demographic Data

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

October 1982

Area	Building	HPSV lamps	Sulfur boxes	Number seen	Male/ Female	Age Ave. Range
Packaging	3-25	+	-	37	21/16	38.2 24-60
Purchase Parts Store	3-25	+	+	26	22/4	41.8 23-60
Pattern Shop	3-56	-	-	19	18/1	44.1 32-62

+ = present
- = absent

TABLE IV

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

October 1982

Prevalence of reported symptoms
(Packaging vs Purchase Parts Stores)

Symptom	Packaging(37)		Purchase Parts Stores(26)		Test of Significance
	#	(%)	#	(%)	
Eye blurring	11	(30)	11	(42)	N.S. *
Eye irritation	16	(43)	18	(69)	0.05<p<0.1 *
Eyes hot	11	(30)	16	(62)	0.01<p<0.02 *
Colors not correct	2	(5)	5	(19)	N.S. **
General eye fatigue, strain	11	(30)	16	(62)	0.01<p<0.02 *
Headache	6	(17) ***	6	(23)	N.S. **
Nausea	3	(8)	1	(4)	N.S. **
Difficulty maintaining attention	3	(8)	1	(4)	N.S. **
Depression, anxiety	2	(5)	4	(15)	N.S. **
Crying episodes	1	(3)	3	(12)	N.S. **
Noticed loss of taste	0	(0)	3	(12)	0.0656 **
Noticed loss of smell	0	(0)	7	(30)	0.0012 **
Tightness in chest	1	(3)	3	(12)	N.S. **

N.S. =Not significant

*=Chi square

**=Fisher's exact test, 1 tail

***= Only 36 respondents-left blank by 1 respondent

Table V

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

October 1982

Prevalence of reported symptoms
(Packaging vs Pattern Makers)

Symptom	Packaging(37)		Pattern-Makers(19)		Test of Significance *
	#	(%)	#	(%)	
Eye blurring	11	(30)	1	(5)	0.0337
Eye irritation	16	(43)	0	(0)	0.01<p<0.001
Hot eyes	11	(30)	2	(11)	N.S.
Colors not correct	2	(8)	0	(0)	N.S.
Headache	6	(17)**	1	(5)	N.S.
Nausea	3	(8)	1	(5)	N.S.
Difficulty Maintaining attention	3	(8)	0	(0)	N.S.
Depression, anxiety	2	(5)	1	(5)	N.S.
Crying episodes	1	(3)	0	(0)	N.S.

N.S.=Not significant

* =Fisher's exact test, 1 tail

** =only 36 respondents-left blank by 1 respondent

TABLE VI

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

October 1982

Prevalance of reported eye symptoms

	Packers	Pattern Makers	
Reporting 2 or more eye symptoms	14	0	14
Reporting less than 2 eye symptoms	23	19	42
	37	19	56

χ^2 (Chi square)=7.67 (Yates correction)
 $P < 0.01$

TABLE VII
Farnsworth-Munsell 100-Hue test scores
(Square root transformed) *

Boeing-Vertol Company
Philadelphia, Pennsylvania
HETA 82-272

A. Test performed first under standard light source (n=4)

#	HPSV Score	Std Light Source	Diff
1	10.0	6.6	3.4
2	11.3	14.0	-2.7
3	8.7	6.0	2.7
4	14.1	10.6	3.5

mean + S.D= 1.73 + 2.97
t=1.16, p>0.05, df=3

B. Test performed first under HPSV lamps first (n=6)

#	HPSV Score	Std light source	Diff
1	10.4	10.0	0.4
2	11.8	6.3	5.5
3	10.0	8.0	2.0
4	8.7	6.0	2.7
5	12.2	12.2	0.0
6	13.3	9.2	4.1

Mean + S.D. = 2.45 + 2.12
t=2.83, p<0.05, df=5

Overall; mean + S.D.=2.16+ 2.36
t=2.89, 0.01<p<0.02, df=9

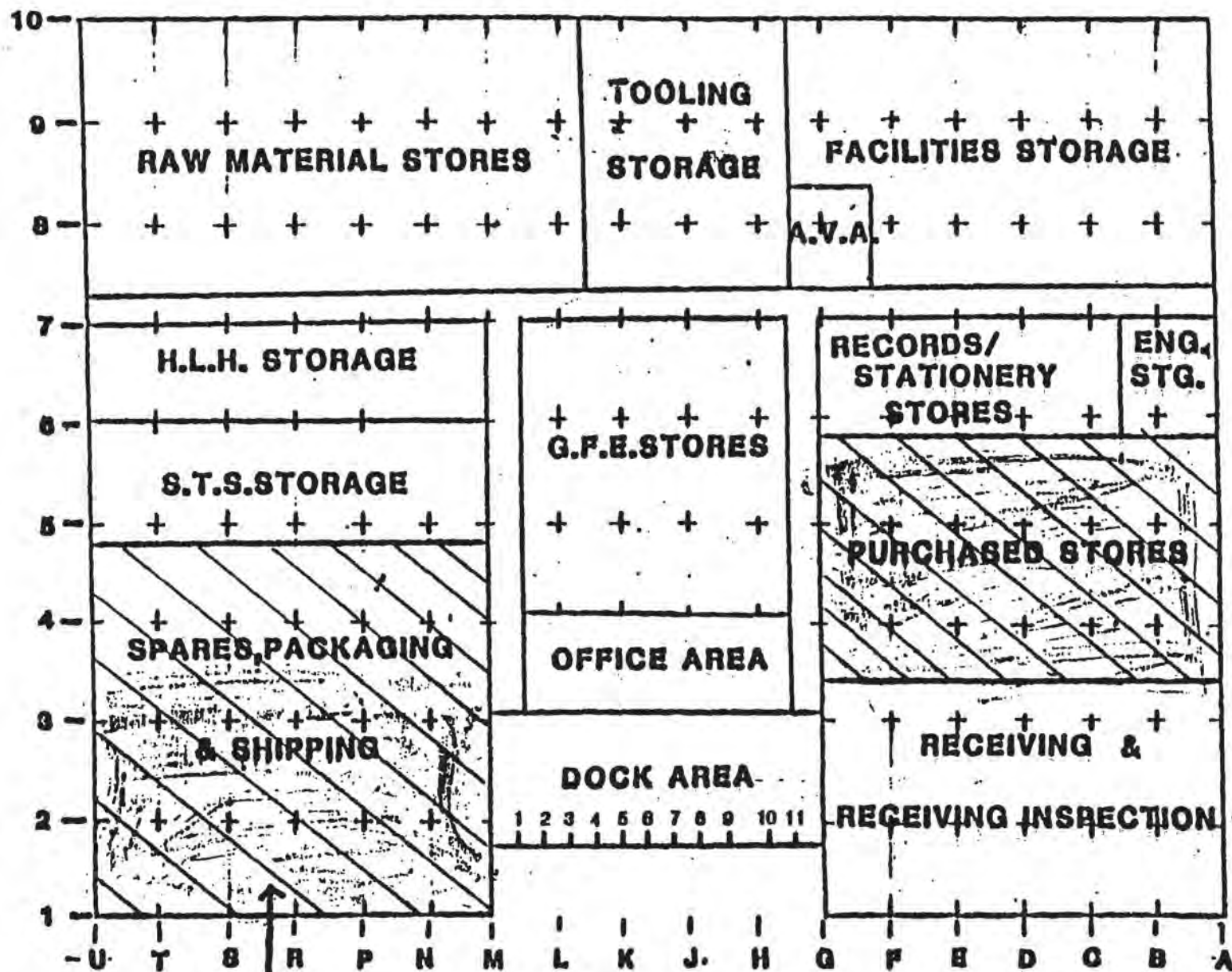
* for those with no evidence of defective color vision only

Appendix I

Text of four eye-related statements on self-administered questionnaire requiring Yes or No answer *

1. One or more of the following: blurred vision, double images, hard to focus
2. One or more of the following eye irritation problems: "eyes are painful, itchy, drying, gritty, watery or burning"
3. One or more of the following eye fatigue problems: "eyes are tired, hot, heavy, achy or strained"
4. One or more of the following: changes in your ability to see colors, colored fringes around objects, colors do not look quite correct

* These statements are part of a questionnaire developed by NIOSH's Division of Biomedical and Behavioral Science (DBBS) for use in evaluating visual symptoms in visual display operators.



Packaging

CENTRAL WAREHOUSE FACILITY BUILDING 3-25

AREAS
INVESTIGATED
FOR SODIUM
VAPOR LAMPS

Figure 1

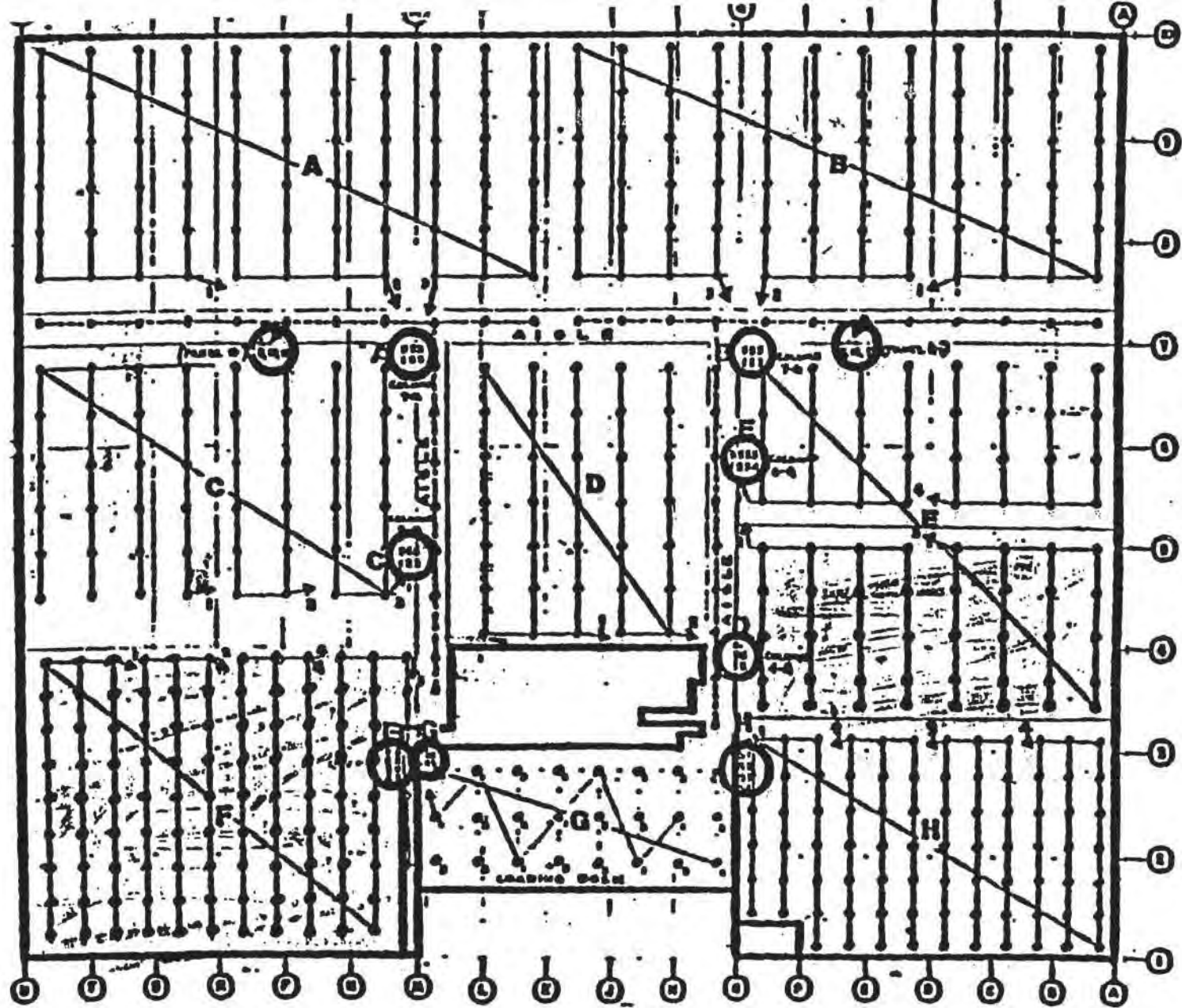


Figure 2

LIGHTING PLAN

FIGURE 3

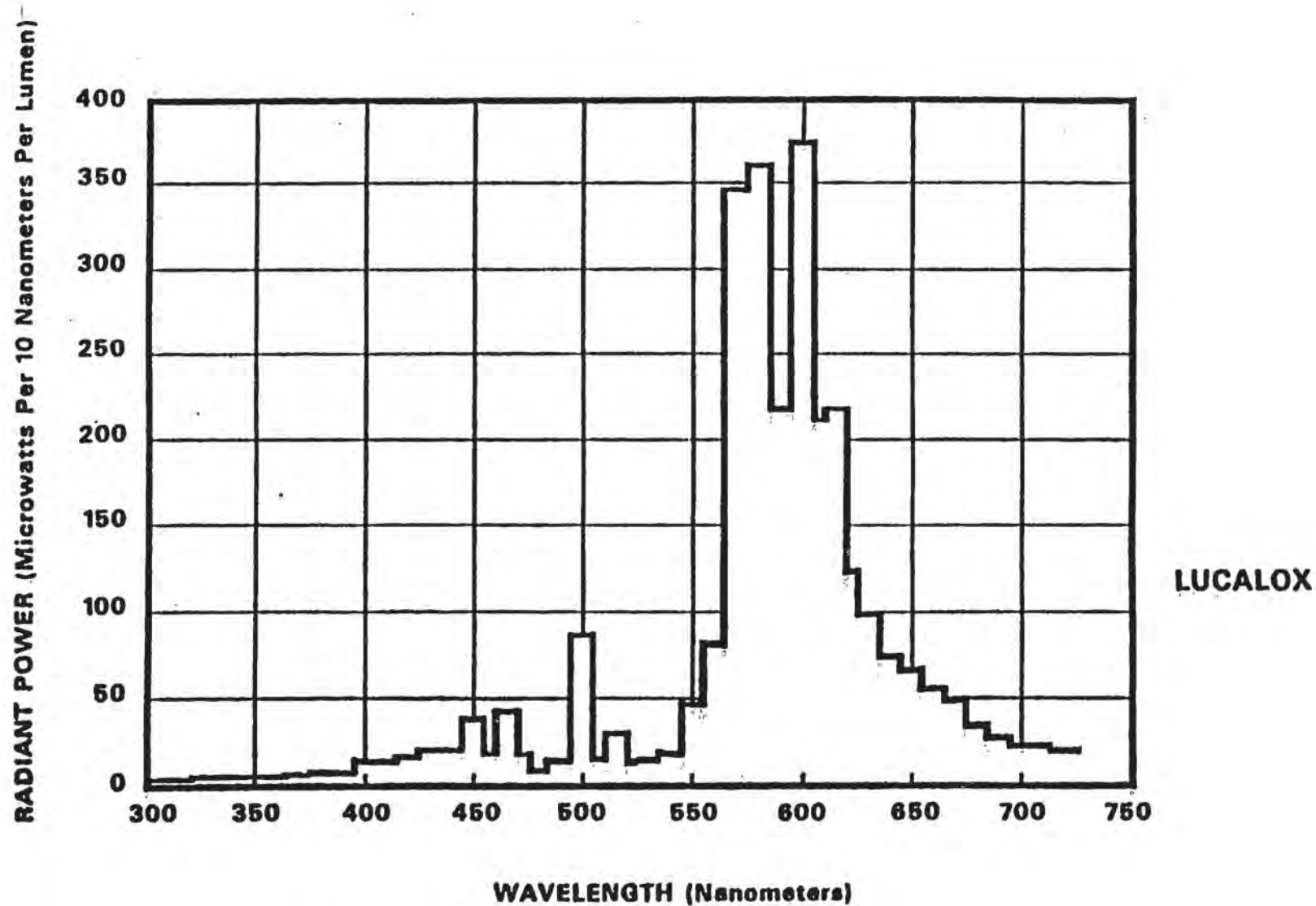


Figure 3. TYPICAL SPECTRAL EMISSION OF 400W HIGH PRESSURE SODIUM VAPOR LAMP