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ELECTRIC BOAT
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I. SUMMARY

In July, 1987, the Metal Trades Council of New London County, AFL-CIO requested that the National Institute for Occupational Safety and Health (NIOSH) evaluate the use of pneumatic hand tools by workers employed as grinders and welders at the Electric Boat Shipyard in Groton, Connecticut. The request reported that approximately 100 of these workers had complained of tingling and numbness in their hands, symptoms compatible with the Hand/Arm Vibration Syndrome (HAVS), a condition caused by excessive exposure to hand-tool vibration.

On April 4-7, 1988, NIOSH conducted a site visit to the Shipyard. Vibration measurements were made on eleven different commonly-used pneumatic hand tools in accordance with the method specified by the American National Standard Institute's Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand.[1] The tool types investigated were a needle gun, a sand tamper, a lead caulker, and grinders and burring tools manufactured by several different tool companies.

The vibration measurements revealed that most of the eleven tools should be limited to 4 or fewer hours of use during an 8-hour work shift to be within the 1989-90 American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Value (TLVs) for hand/arm vibration exposure. Only the Stanley Offset Grinding Wheel, one of the True Power Burring Tools, and the Chicago Pneumatic #3 Corner Drill had vibration levels determined in one or more measurements that would allow usage from 4 to 8 hours per day. The other eight tools had levels of vibration measured which would restrict their usage during an 8-hour work shift from less than 4 hours to no usage whatsoever (levels greater than 12 meters/second^2[m/sec^2]). The lead caulker (pneumatic chipping hammer), sand tamper, and three of the 4 types of burring tools had vibration levels in excess of the ACGIH TLV of 12 m/sec^2.

A local occupational medical clinic reported that over 300 Electric Boat Shipyard employees had been seen because of tingling and numbness in their hands and/or finger blanching [symptoms compatible with hand/arm vibration syndrome (HAVS)]. Physicians at this clinic had also distributed a questionnaire to a sample of grinders, welders, and shipfitters inquiring about symptoms compatible with HAVS. Approximately 70% of grinders, 25% of welders, and 10% of shipfitters reported finger blanching.

Because of the small number of tools measured, it would be inappropriate to generalize these vibration measurements to all of the tools used at the shipyard. However, because of the large number of workers seen at the occupational medicine clinic for symptoms compatible with HAVS, because the tool measurements revealed that restrictions in the times of use for most of the tools was warranted, and because no administrative procedure existed to determine and implement these tool use restrictions, the NIOSH investigators conclude that a health hazard existed at the shipyard. Recommendations to reduce vibration exposure are made in Section VII.

KEY WORDS: SIC 3731 (Shipyard), Vibrating Tools, Hand Transmitted Vibration, Hand Arm Vibration Syndrome (HAVS), Vibration White Finger (VWF)

II. BACKGROUND

In July, 1987, the Metal Trades Council of New London County, AFL-CIO requested that investigators from the National Institute for Occupational Safety and Health (NIOSH) evaluate the use of pneumatic hand tools by workers employed as grinders and welders at the Electric Boat Shipyard in Groton, Connecticut. The request reported that approximately 100 of these workers had complained of tingling and numbness in their hands, symptoms compatible with the hand/arm vibration syndrome (HAVS), a condition caused by excessive exposure to hand-tool vibration.

On April 4-7, 1988, a NIOSH field team visited the Shipyard to meet with Electric Boat management personnel and representatives from the Metal Trades Council. After proper clearances had been obtained for the NIOSH team, an opening conference was held on April 4 to gather facts about the health and work activities of the employees. At this time, it was explained that vibration measurements would be taken on a selected number of pneumatic hand tools in use in the shipyard to assess the magnitude of the vibration impinging on the workers' hands. A walk-through tour of the areas where these tools were used was then conducted. Beginning on April 5, vibration measurements were made over the next two and one-half days.

III. METHODS

Vibration measurements were conducted at the work site using hand tools which had been checked out of the tool crib by the employees. To the extent possible, these measurements were obtained with the employee using the tool on the ship's hull in his normal work routine. Information on the vibration levels was obtained from eleven different pneumatic hand tools. The tool types investigated were a needle gun, a sand tamper, a lead caulker, and grinders and burring tools manufactured by several different tool companies. The vibration data measurement runs were generally collected for durations of two minutes and were repeated at least once if permitted by the work task. There were also two instances where the same model-numbered tool from the same manufacturer was measured in different locations, operated by different workers.

Measurements were made in accordance with the orthogonal direction definitions specified by the American National Standard Institute's Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand (ANSI S3.34-1986).[1] According to the standard, a triaxial configuration of measuring transducers is mounted onto the tool handle. A basicentric coordinate system uses the head of the third metacarpal bone as the origin and defines the Z-axis as the longitudinal axis of the bones of the arm. The X-axis is perpendicular to the palm of the hand ("up and down") when the palm faces forward. The Y-axis passes through the origin and is perpendicular to the X-axis ("side to side"). This coordinate system for the hand is shown in Figure 1.
Three Columbia Research Model 6064 piezoelectric accelerometers were fixed in a small metal cube welded to a hose clamp in the triaxial fashion referred to above. The clamp and accelerometers were tightened onto the handle of the pneumatic tool being measured. The triaxial accelerometer assembly was connected through a 20-ft. charge cable to a tape recorder where the acceleration signals from these three transducers were converted to voltages, amplified by individual charge amplifiers, integrated in the FM tape recorder, and recorded on their respective data channels. The data were recorded on a Bruel & Kjaer Model 7006 FM instrumentation recorder and stored for later analysis on 1/4" instrument grade magnetic recording tape. The recorder has four-channel capability, allowing for the simultaneous acquisition of data from all three orthogonal axes, as well as a timing channel. A time code was

placed on the tape with a Datum Model 9300 Time Code Generator/Reader. Using a tape speed of 1.5 in/sec, a frequency range from 0.5 Hz to 1600 Hz was obtained.

Before and after data collection, the three piezoelectric accelerometers were dynamically calibrated according to the manufacturer's instructions using a Bruel & Kjaer Model 4291 Accelerometer Calibrator. As measurements were being made, a monitoring oscilloscope (Tektronix Model 321) was observed to insure that only true vibration data was being recorded and that no signal overloading (clipping) was occurring.

The analysis of the tape-recorded acceleration data was performed with a Hewlett-Packard Model 3561A Spectrum Analyzer. This analyzer is capable of doing real-time frequency analyses of the 1/3 octave band center frequencies of 6.3 Hz to 1250 Hz. Because of the long integration times necessary to reliably analyze the lower frequency bands, usually only 2-4 continuous samples were included in each of the spectral analyses. This number of samples, however, incorporates about 50-100 seconds of real-time continuous vibration data.

IV. EVALUATION CRITERIA

Hand-Arm Vibration Syndrome (HAVS) can affect workers who have extensively used vibrating hand tools.[2] Loggers who use gasoline-powered chain saws, foundry workers who use pneumatic air hammers and grinding wheels, and miners who use pneumatic drills have been the occupational groups most extensively studied. Usually the first symptoms experienced by affected workers consist of numbness and tingling of the hands and fingers similar to that reported by people with carpal tunnel syndrome. After a variable period of tool use (depending on the intensity of the vibration produced by the tool), workers will notice that one or more finger tips become white and numb when the workers are exposed to cold. The worker may also notice decreased hand dexterity and impaired sense of touch in the hands. If vibration exposure continues, symptom severity can increase to the point where all fingers of both hands frequently experience local vasospasm and finger blanching upon even mild cold exposure. Occasionally tissue necrosis in the fingers can occur. The Hand-Arm Vibration Syndrome is more extensively discussed in NIOSH Current Intelligence Bulletin Number 38.[2]

The criteria used in the evaluation of hand-arm vibration exposure are twofold: 1) The American National Standard Institute's Guide for the Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand (ANSI S3.34-1986),[1] and 2) American Conference of Government Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) and Biological Exposure Indices for 1989-90.[3]

1. The ANSI standard specifies the recommended method for the measurement, data analysis, and reporting of human exposure to hand-arm vibration. The standard format for reporting the vibration spectral data is to analyze the root mean square (rms) acceleration levels in meters per second squared (m/sec^2) in one-third octave bands in the frequency range from 5.6 Hz to 1400 Hz. This format is followed for each of the three orthogonal directions of vibration.

   Additionally, the ANSI standard contains three appendices, which are not part of the standard, but do provide information on the assessment of exposure to hand-arm vibration for each center frequency of the discrete one-third octave bands analyzed.

Figure 2 is reproduced from the standard and is based on regular daily exposures extending over many years. Occasional days of exposure to vibration levels higher than that shown in the reported exposure zones is not necessarily harmful. The time values given in the zones are for the actual length of tool use and not the length of the work day.

2. The ACGIH Threshold Limit Values (TLVs)[3] state that the magnitude of the vibration of the tool in each direction (X, Y, Z) during normal operation shall be expressed by the rms value of the frequency-weighted component accelerations, in units of m/sec^2. The direction with the largest rms acceleration forms the basis for the exposure assessment. If the total daily vibration exposure in a given direction is composed of several exposures of different rms accelerations, the equivalent frequency-weighted component acceleration in that direction shall be determined by using a time-weighted average.

In this investigation of pneumatic tool assessment, linear integration of the tool's acceleration for the time period during which each tool was measured (1-2 minutes) was assumed to be representative of the daily work task. If these work conditions are unchanged for the entire work day, then the measured acceleration levels are compared to the daily exposure TLV for hand-arm vibration (Table 1) to assess the exposure limits. When one compares the two vibration exposure standards, it should be noted that they are not directly comparable. The ACGIH TLV is a single number which represents the summed power values for each of the 1/3 octave bands after each band has been weighted according to the filter characteristics given in the TLV. The ANSI standard, however, considers each of the 1/3 octave bands separately as it compares them to the exposure time zones. Thus, there may be instances where the overall ACGIH acceleration value may limit tool usage to less than 1 hour per day while the individual 1/3 octave band values from the same tool may only reach the 1-2 hour line of maximum tool usage. This difference is due entirely to the manner in which the two different evaluation criteria are calculated.

Information for both evaluation standards is based on available knowledge about the latent intervals (time between first using vibrating tools and the first appearance of finger blanching) associated with vibration exposure of various magnitudes. Considering the available knowledge and confounding factors such as grip force, grip orientation, ergonomics, intermittent exposures, temperature, etc., it is not possible to provide precise guidelines for each exposure condition. Therefore, the tables and graphs of vibration assessment present "zones" of daily exposure time. These criteria are based on relatively uninterrupted vibration exposures. They also assume a good coupling of the worker's hand to the tool. For any other hand-arm vibration conditions, this assessment may be overly conservative, that is, the hazard may be less.

The ACGIH TLVs were formulated as guidelines to be used in conjuction with anti-vibration tools, anti-vibration gloves, proper work practices, and a conscientiously-applied medical surveillance program to protect workers from the adverse affects of hand-arm vibration exposure. The tool acceleration levels and durations of exposure in the ACGIH guidelines represent conditions under which it was believed that <u>most</u> workers could be exposed without progressing to <u>severe</u> signs of HAVS (episodes of extensive blanching of all fingers and definite interference with activities at work and home).

The ACGIH vibration exposure guidelines will not necessarily prevent the development of <u>all</u> hand morbidity associated with vibration exposure. Extrapolation of data presented in Appendix A of the ANSI vibration standard suggests that after 4 hours of daily use of a vibrating tool with a frequency weighted acceleration of 4 m/sec^2 for a period of about 17 years, 50% of a workforce cohort so exposed could be expected to have experienced episodes of at least initial finger blanching. If the tool used had a weighted acceleration of 6 m/sec^2, 50% of the workforce could be expected to have experienced finger blanching after about 11 years. For a tool with a weighted acceleration of 12 m/sec^2, 50% of the workers could have such symptoms after working only 5 to 6 years.

V. RESULTS

Acceleration data were collected from eleven different types of pneumatic hand tools. For this report, the tools will be grouped as follows:

A. Grinders Group

1. Dresser Cleco 6000 Grinder, Model 15GL60RA (2 tools)
2. Chicago Pneumatic "Whirlybird" Grinder/Vertical Sander, Model CP 9122 (2 tools)
3. Stanley Grinder/Offset Wheel, Model G30LA2

B. Burring Tools Group

1. Chicago Pneumatic Large Straight Burr, Model 9113G
2. Stanley Offset Burring Tool, Model G30LA2
3. Dresser Cleco Burring Tool, small, Model 11GLF250
4. True Power "Welder's Burr" Burring Tool, Model AP-210 (2 tools)

C. Other Pneumatic Tools

1. Von Arx Offset Needle Gun, Model MDP-1
2. Chicago Pneumatic Caulking Gun/Chipping Hammer, Model CP 4112
3. Chicago Pneumatic Corner Drill, Model CP 3450
4. Dresser Cleco Sand Tamper, Model AT 6874

The data were tape recorded while the operator was performing real work on a particular task in construction (one task was simulated). The tasks were varied, ranging from grinding external weld beads, to using the grinding wheel edge to grind slots by holding the wheel perpendicular to the work face. The ergonomic positions were quite varied, with workers standing, sitting, bending, or even lying prone at the work site. Some workers, while sitting, would brace their forearm against their knees. In some situations, the grinding or burring was done at a higher than head level, with the arms raised.

All operators observed in the vibration tests (three females and eight males) wore work gloves of some type. Some of the gloves had leather palm areas, but many wore "Impact-o-Gloves", a cotton work glove lined with Viscolast ER 505 which is a material advertised to decrease the transmission of vibration to the hand. Workers told NIOSH investigators that the operators would order the smallest size vibration glove available in order that the glove would fit tightly over the palm, so as not to "bunch up" and cause discomfort in the palm area.

The acceleration data collected for the three groupings of pneumatic tools are presented in Tables 2-4. Each Table indicates the kind of tool measured, the dominant axis of vibration based on the weighted rms acceleration value, the range of acceleration levels in m/sec^2 for the dominant axis over the repeated measurements of the tool, a comparison of the low and high acceleration value to the ACGIH TLV for hand-arm vibration, and a brief description of the worker's activity during the recording period. Additionally, a spectral plot of the three axes of vibration of the measurement of the tool for the high and low range acceleration values is given for each tool listed in the tables. These plots are included in Appendix A.

Overlayed on the spectral plots in this report's Appendix A is the upper limit of the time zones referred to in the ANSI standard's Appendix A. Thus, if the dark spectral line is below the first solid line, the worker can use the tool for the 4 - 8 hour time zone. If the spectral line crosses into the next layer, the worker is allowed a 2 - 4 hour usage period. A crossing into the next higher layer is the 1 - 2 hour zone, and a spectral plot which crosses all three zone boundaries may be in excess of the ANSI appendix to the standard. It should be noted that the ANSI document does allow for a 1/2 - 1 hour zone, but that has not been included in the spectral plots presented in this report. This was done for clarity and simplicity in the plotting of these data.

Generally, the vibration measurements revealed that most of the eleven tools should be limited in their usage during an 8-hour work shift. Only the Stanley Offset Grinding Wheel, one of the True Power Burring Tools, and the Chicago Pneumatic #3 Corner Drill had vibration levels determined in one or more measurements that would allow usage from 4 to 8 hours per day. The other eight tools had levels of vibration measured which would restrict their usage during an 8-hour work shift from less than 4 hours to no usage whatsoever (levels greater than 12 m/sec^2). The majority of the burring tool measurements were in excess of the ACGIH TLV of 12 m/sec^2. The True Power "welder's burr" was the only burring tool which did not exceed an acceleration of 12 m/sec^2 on any measurement.

There were two situations where the type of work being done influenced the levels of acceleration. One instance was with the Chicago Pneumatic Whirlybird Grinder (b). The operator was working on the hull at the outer torpedo doors. A cut had been made into the hull, and the grinder operator was smoothing the area around the cut on the surface of the hull as well as smoothing the cut metal edge. This operation necessitated that the worker either place the grinding wheel parallel to the surface of the hull with the majority of the wheel touching the surface (measurement #1) or at a perpendicular orientation to the hull with only a minimal part of the grinding wheel in contact with the metal edge of the hull (measurement #2). As can be seen in Table 2, the second work condition resulted in higher vibration levels than the condition where a large portion of the grinding wheel was in contact with the work piece surface. This is most likely due to the small surface area of the hull's metal edge and the need for the operator to direct the grinding wheel into the restricted area of the cut. The second instance of the work influencing the measurements was with the Chicago Pneumatic #3 Corner Drill. The operator made two different drill holes during the measurement period. For the first measurement, a brace which attached to the drill was used. In the second instance, the brace was removed and the drill was hand held by the operator. The former situation resulted in an acceleration level of 1.1 m/sec^2, and the latter work practice yielded a 12.5 m/sec^2 acceleration value. Obviously, the additional support from the brace reduced the amount of vibration being emitted by this rather large drill.

During the course of the site visit, the NIOSH investigators were given the opportunity to use some of the pneumatic tools in the work place. The group of burring tools were the most difficult to operate for the untrained user. They would have a propensity to grab into the surface and "run away" from the user as he hung onto the tool. Workers said that a great deal of strength was needed to control the tool as it did its work. The strength needed to operate the grinders and the other types of tools, which were larger and heavier, was to lift and hold them, rather than control them during operation.

It must be emphasized that the measurement conditions under which the Chicago Pneumatic Chipping Hammer (lead caulker) was tested were simulated to try to mimic the typical workplace conditions. This was necessary because of the inaccessibility of work areas where lead was being used. A square piece of steel was placed into a square wooden box and the caulker was used to spread lead into the seam formed between the steel block and wooden box. This proved to be less than an adequate simulation of actual worksite practices. The metal block and wooden box had a great deal of play in the way in which they fit together. This would cause the work piece to rattle around as the operator attempted to caulk lead into the seam between the block and box. The actual work performed on the ship would not cause this kind of extraneous movement of the work piece. These less than perfect conditions most likely affected the acceleration levels measured on this pneumatic tool.

VI. DISCUSSION AND CONCLUSIONS

Because of the complicated nature of the measurement scheme and the limited time available, the number of tools measured during the site visit is small when compared to the hundreds of pneumatic hand tools used at Electric Boat. It necessarily takes a great deal of time to correctly make these kind of measurements. Because of the small number of tools measured, it is impossible to generalize these measurements to all of the tools used at the facility. Nevertheless, the measurements, which were made at the work site under actual work conditions, are at least indicative of the magnitude of acceleration levels which can be obtained with pneumatic hand tools of the types studied. Because the majority of the acceleration measurements revealed that a restriction in the time of use of the tools was warranted, Electric Boat should be aware of the potential for excess hand-arm vibration exposure in workers who must routinely use these kinds of tools in performing their jobs.

Workers reported that chipping hammers had formerly been used to clean many of the weld sites, but that gradually burring tools had been substituted for the chipping hammers to perform the rough removal of metal. The acceleration levels recorded for burring tools revealed that the current ACGIH TLV was exceeded in the majority of cases. It appears that the objective of quickly removing metal from the hull may be the reason for the high levels of vibration. Doing a lot of work in a short period of time yields high levels of vibration, and burring tools require extra effort to hold them in place on the work piece surface to keep them from radically moving along the surface. If one would slowly remove the metal, then the higher peak acceleration levels would be reduced, thus reducing the integrated vibration per hour of tool use. It will take additional time to remove metal with a grinder; however, the vibration levels from this class of tool is less than the accelerations found in the burring tools.

In the shipyard, tools are normally checked out of a tool crib by the employee at the beginning of the shift or when a particular tool is needed. Workers reported that tools were only repaired when they failed completely and could thus perform no work. One of the burring tools measured during the study had a shaft with a very noticeable amount of play. This tool, whose shaft would wobble back and forth when the tool was moved in the operator's hand, had a measured acceleration ranging from 7.9 to 8.7 m/sec^2. The looseness of the shaft probably added to the high vibration level being emitted by this tool. The same model of pneumatic burring tool measured at another shipyard worksite had the lowest acceleration of any tool measured (1.0 to 2.7 m/sec^2). A program of routine preventative maintenance for pneumatic tools is needed. Routine inspection of the defective burring tool following usage may have identified it as one needing repair or one which should have been removed from the tool crib.

The observation of reduced vibration in the #3 corner drill through the use of an additional brace is a work practice which should be encouraged and continued. This type of tool should not be used as a hand-held tool. The practice of using a brace should be pursued to see if other tools would lend themselves to this use condition. There may be situations where mechanical supports could be used in jobs which require a lot of tool usage. The operator would have less contact with the tool, and the vibration levels may be reduced during the periods where the tool must be directed.

The majority of the tool measurements made in the NIOSH survey had frequency-weighted vibration levels in the range of 6 to 12 m/sec.^{2} As discussed in Section III, workers exposed to vibrating hand tools producing a frequency-weighted acceleration in the range of 6 to 12 m/sec^2 could be expected to have a median latent interval (the time between beginning such tool use and first experiencing finger blanching) of 6 to 11 years. If employees were using a tool of much higher acceleration (e.g., the burring tool measured at 79 to 88 m/sec^2) symptoms could begin much earlier.

In the last 4 years, over 300 employees from Electric Boat who used vibrating tools in their work have been evaluated at a local occupational medical clinic because of numbness and tingling in their hands and/or finger blanching. It is of interest that the average latent interval to initial finger blanching was about 8 to 10 years for affected workers, but some workers experienced symptoms after only 2 to 3 years.

At the time of the NIOSH site visit, the majority of vibrating tools were used by grinders and welders. Approximately 500 workers were employed as grinders, whose primary tasks involved using grinding tools, such as large and small pneumatic grinding wheels, or smaller burr tools. The approximately 800 welders performed "incidental grinding", mostly using small burr tools 1 or 2 hours per day. In 1988, the local occupational medicine clinic distributed a questionnaire to a sample of grinders, welders, and shipfitters. Seventy percent of the grinders and 25% of the welders reported experiencing finger blanching. Ten percent of the shipfitters (who use vibrating tools less frequently) reported experiencing finger blanching.

The reported fact that over 300 workers have been medically evaluated for symptoms compatible with the hand/arm vibration syndrome, and NIOSH's tool vibration survey results indicate that additional measures to lower hand/arm vibration exposures and to medically monitor employees at Electric Boat are necessary. The following recommendations are made to help achieve those goals.

VII. RECOMMENDATIONS

1. Electric Boat should make every effort to ensure the use of pneumatic grinding and burring tools that have been designed to minimize the amount of vibration energy transmitted to the users' hands and arms.

2. The company has recently improved its ability to measure the vibration levels of hand-held vibrating tools. The tool models found to have markedly high vibration levels in the NIOSH survey (the chipping hammer, sand tamper, and several of the burr tools) should be carefully evaluated by the company regarding their vibration characteristics. If the excessive tool acceleration levels found in the NIOSH survey are representative of those tool models, those tool models should be replaced with anti-vibration tools as soon as possible. The remaining vibrating tool classes used in the shipyard should then be systematically evaluated to determine their vibration characteristics. Until all vibrating tools in use at the shipyard produce levels of vibration less than 4 m/sec^2, a program should be instituted to restrict the time of use of tools exceeding that level to time periods well within those allowed by the ACGIH TLV.

3. The present tools should receive corrective and periodic maintenance to the manufacturers specifications to minimize their vibration energy during operation. If these tools become so worn that they cannot be repaired (e.g., damaged bearings, bushings, etc.), the tool should be replaced immediately.

4. Some of the air-powered tools have an air exhaust that causes the tool and the user's hand to become cold when the tool is in use, sometimes even developing frost on the metal surface and handles. Since affected workers may have "white finger" attacks precipitated by this cold exhaust air, tool modifications to redirect this air exhaust away from the user's hands should be considered.

5. A formal training program should be established by Electric Boat to instruct current and new employees in the proper work practices of using vibrating hand tools. The techniques of grasping the tools as loosely as possible consistent with safe work practices should be taught. Grasping the tools lightly will decrease the mechanical coupling and thus the vibration energy absorbed by the hand.

6. NIOSH is releasing a Criteria Document entitled "Criteria for a Recommended Standard...Occupational Exposure to Hand-Arm Vibration", NIOSH Publication No. 89-106, September, 1989. This document should be available in the near future. Chapter VII is included in this report as Appendix B. This chapter, called "Methods for Worker Protection", contains control strategies which may be quite useful for Electric Boat's industrial hygiene and safety programs. The topics covered are engineering controls, work practices, ergonomic considerations, protective clothing and equipment, worker training, and medical monitoring of workers. As indicated, any effective vibration control procedures need data detailing the hazard, that is, the "dose" to which the worker is exposed to during the workday. For vibrating tools, this would be the vibration acceleration in m/sec^2, measured in three basicentric coordinates, and the time in minutes per day the tool is actually in use. Of utmost importance in this chapter is the discussion concerning the need of at least yearly medical evaluation of workers using vibrating tools so that appropriate action may be taken if they begin to experience significant signs or symptoms of HAVS.

   The above measures, along with appropriate selection of ergonomically designed tools that produce the least vibration required for the task, and proper training of workers, supervisors, and industrial hygiene/medical professionals to recognize the very early signs and symptoms of Hand-Arm Vibration Syndrome, are a necessary first step in reducing this occupational health problem.

As a general observation, the NIOSH field team noted that some of the grinders using vibrating tools, and also some welders, were not using proper face and eye protection. In addition, in certain hull areas no welding curtains were used, nor was there any notification given to adjacent personnel nearby that welding was about to begin. The safety office should make an effort to increase employee awareness of the need to use face and eye protection.

VIII. REFERENCES

1. American National Standards Institute. Guide for the measurement and evaluation of human exposure to vibration to the hand. ANSI S3.34-1986, New York, New York,: Acoustical Society of America, 1986.

2. NIOSH Current Intelligence Bulletin Number 38, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

3. American Conference of Governmental Industrial Hygienists. Threshold limit values and biological exposure indices for 1989-1990., Cincinnati, Ohio.

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1. Metal Trades Council of New London County, AFL-CIO
2. Electric Boat Shipyard, Groton, Connecticut
3. OSHA, Region I

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

DISCLAIMER

Mention of the name of any company or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

TABLE 1

ACGIH Threshold Limit Values for Hand-Arm Vibration 1989-90

Electric Boat
Groton, Connecticut
HETA 87-348

Total Daily Exposure Duration [a]	Values of the Dominant, Frequency-Weighted, rms Component Acceleration Which Shall not be Exceeded[b]
	m/s^2
less than 8 hours	4
less than 4 hours	6
less than 2 hours	8
less than 1 hour	12

(a) The total time vibration enters the hand per day, whether continuously or intermittently

(b) Usually one axis of vibration is dominant over the remaining two axes. If one or more vibration axis exceeds the Total Daily Exposure, then the TLV has been exceeded.

Table 2
Acceleration Levels in the Dominant Axis for Grinding Tools
Electric Boat
Groton, Connecticut
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Tool	Dominant Axis	Acceleration Range (m/s^2)	Exposure Assessment	Work Activity
Dresser Cleco 6000 (a)	X	7.3 - 12.4	Less than 8 hours to TLV exceeded	Grinding welds on hull exterior
Dresser Cleco 6000 (b)	Y	5.6 - 9.6	Less than 4 hours to less than 1 hour	Grinding metal bar mounted in vise
Chicago Pneumatic Whirlybird (a)	Z	6.5 - 9.8	Less than 2 hours to less than 1 hour	Grinding welds on hull exterior
Chicago Pneumatic Whirlybird (b)				
Measurement #1	Z	4.5 - 8.9	Less than 4 hours to less than 1 hour	Grinding on surface of outer torpedo doors
Measurement #2	Y	13.0 - 15.7	TLV exceeded	Grinding on cut into hull at outer torpedo doors
Stanley Offset Wheel	Y	3.7 - 6.7	Less than 8 hours to less than 2 hours	Grinding edge of metal plate mounted in vise

Note: (a) and (b) refer to different measurements on the same brand of tool. Measurement #1 and #2 refer to different work activities using the same tool. Exposure assessments are all made with reference to the ACGIH criteria.

Table 3

Acceleration Levels in the Dominant Axis for Burring Tools

Electric Boat
Groton, Connecticut
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Tool	Dominant Axis	Acceleration Range (m/s^2)	Exposure Assessment	Work Activity
Chicago Pneumatic Large Straight Burr	Z	10.7 - 24.2	Less than 1 hour to TLV exceeded	Cleaning & smoothing welds in battery well
Stanley Offset Burr				
#1) metal bit	Z	79.7 - 88.1	TLV exceeded	Cleaning & smoothing
#2) wire brush	Y	22.6	TLV exceeded	metal in torpedo room
#3) sanding disc	Z	16.7	TLV exceeded	
Dresser Cleco Small Burr	X	34.7 - 48.7	TLV exceeded	Cleaning metal edge on on torpedo shutter
True Power "Welder's Burr" (a)	Z	7.9 - 8.7	Less than 2 hours to less than 1 hour	Cleaning weld in periscope well
True Power "Welder's Burr" (b)	Z	1.0 - 2.7	Less than 8 hours	Cleaning metal in torpedo room

Note: (a) and (b) refer to different measurements on the same brand of tool. Measurement #1, #2, and #3 refer to different work activities using the same tool. Exposure assessments are all made with reference to the ACGIH criteria.

Table 4

Acceleration Levels in the Dominant Axis for Other Pneumatic Tools

Electric Boat
Groton, Connecticut
HETA 87-348

Tool	Dominant Axis	Acceleration Range (m/s^2)	Exposure Assessment	Work Activity
Vonarx Offset Needle Gun	Y	6.2 - 7.0	Less than 4 hours	Remove paint on over-head beam in torpedo room
Chicago Pneumatic Chipping Hammer	Z	22.7 - 187.7	TLV exceeded	Caulking lead; NIOSH measurements made in simulated situation with lead being spread around metal block placed in wooded box. Different tamping tools used during measurement
Chicago Pneumatic #3 Corner Drill	Y	1.1 - 12.5	Less than 8 hours to TLV exceeded	Drilling holes in metal in torpedo room
Dresser Cleco Sand	Y	32.3 - 39.5	TLV exceeded	Tamping sand around die Tamper in wooden box

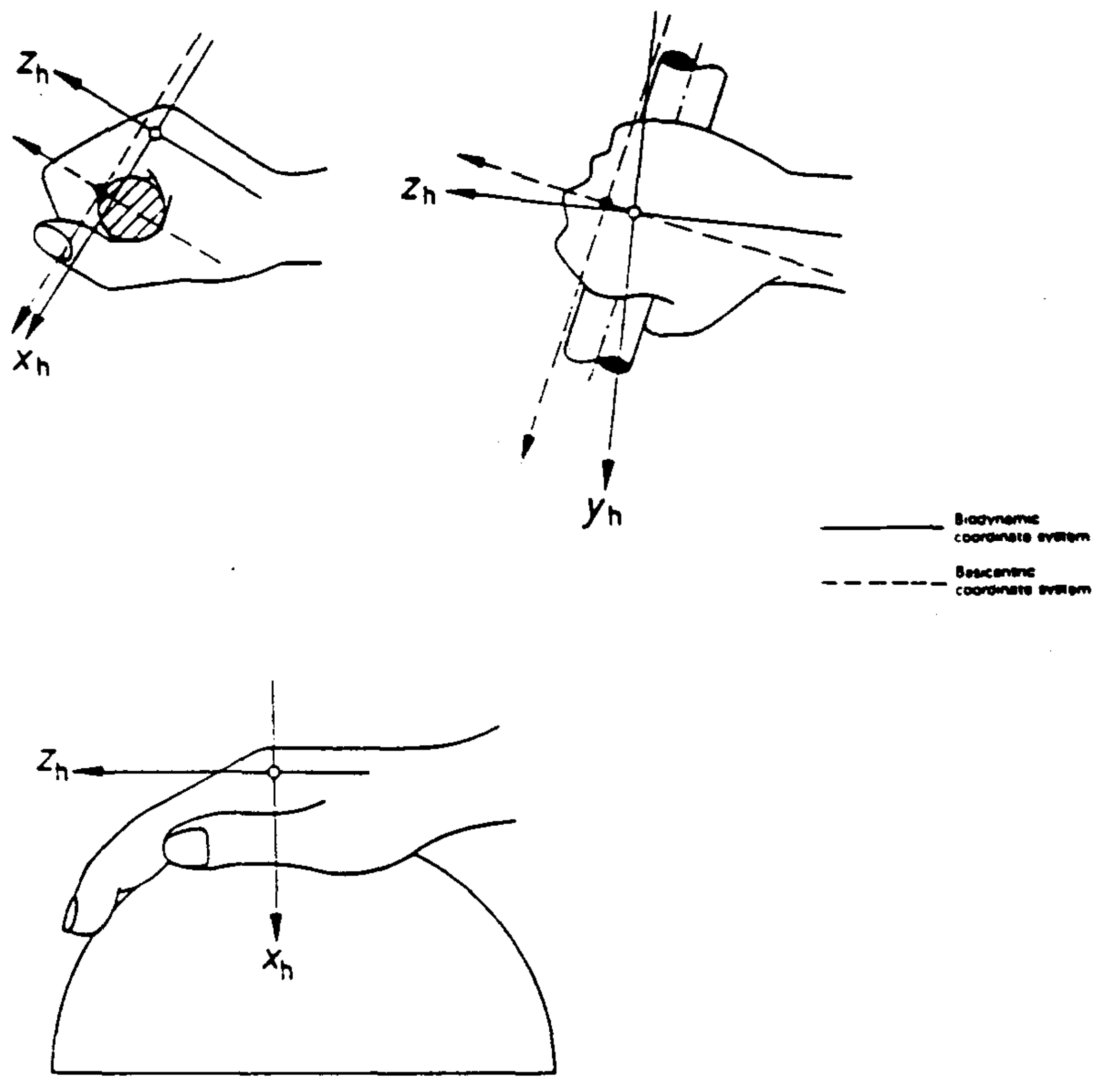
Note: Exposure assessments are all made with reference to the ACGIH criteria.

Figure 1

ELECTRIC BOAT

(a)

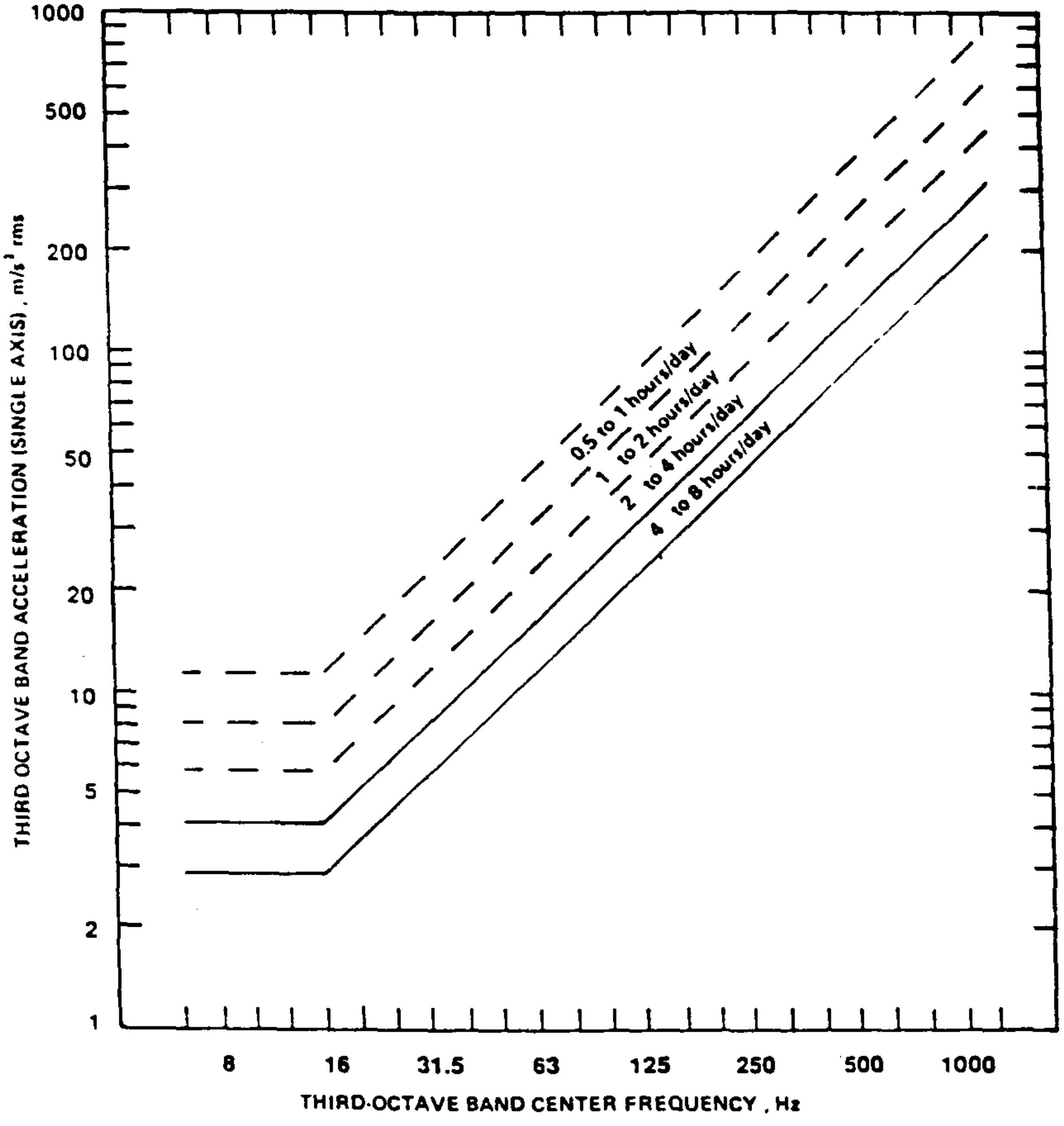
(b)



Coordinate system for the hand. The origin of the system is deemed to lie in the head of the third metacarpal and the $z_{(hand)}$ axis to be defined by the longitudinal axis of that bone. The x axis projects forwards from the origin when the hand is in the normal anatomical position (palm facing forwards). The y axis passes through the origin and is perpendicular to the x axis. When the hand is gripping a cylindrical handle, the coordinate system shall be rotated so that the y_h axis is parallel to the axis of the handle. (a) "Handgrip" position. In this position, the hand adopts a standardized grip on a cylindrical bar of radius 2 cm. (b) "Flat palm" position. In this position, the hand presses down onto a ball of radius 5 cm.

Figure 2

ELECTRIC BOAT



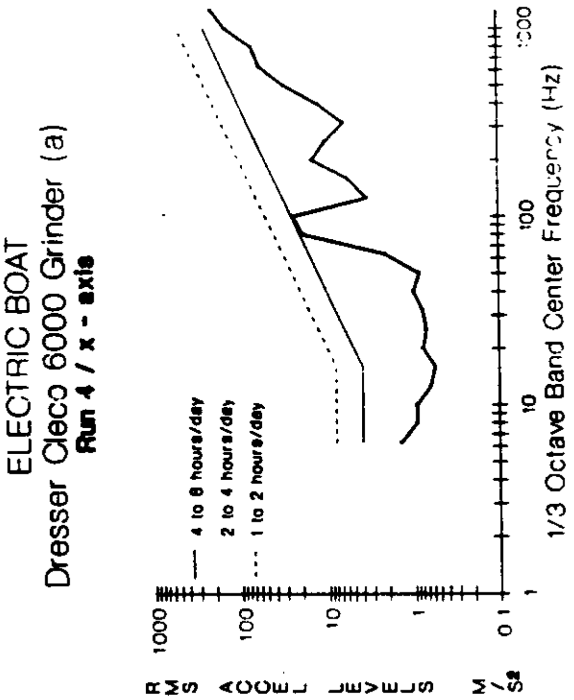
Vibration exposure zones for the assessment of hand-transmitted vibration. The zones of daily exposure time are for rms accelerations of discrete frequency vibration and for narrow-band or broadband vibration analyzed as third-octave band rms acceleration. The values are for the dominant single axis vibration generating compression of the flesh of the hand. The values are for regular daily exposure and for good coupling of the hand to the vibration source.

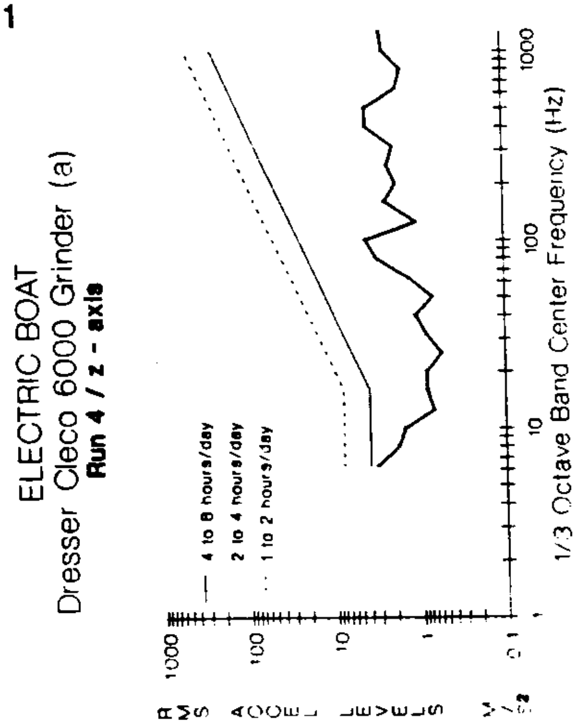
APPENDIX A

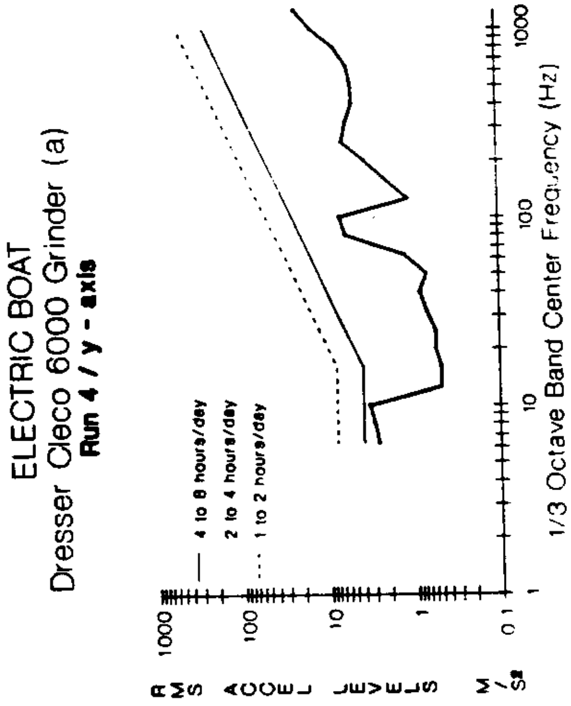
VIBRATION MEASUREMENT RESULTS

Appendix A

Figure 1



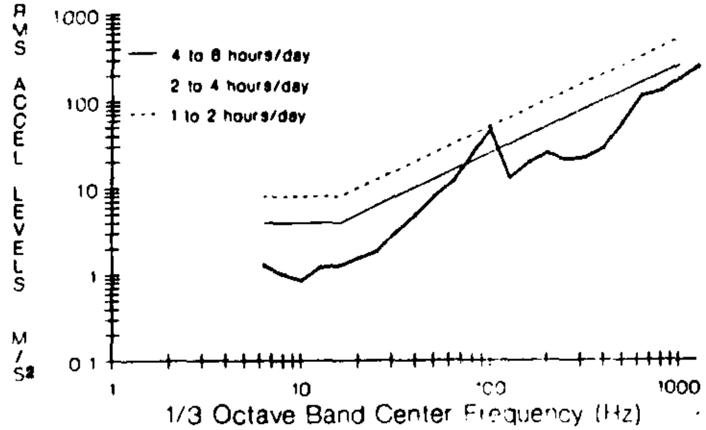




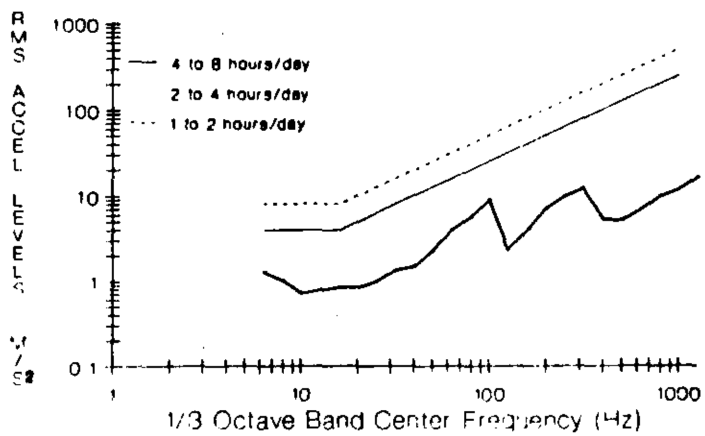
Appendix A

Figure 2

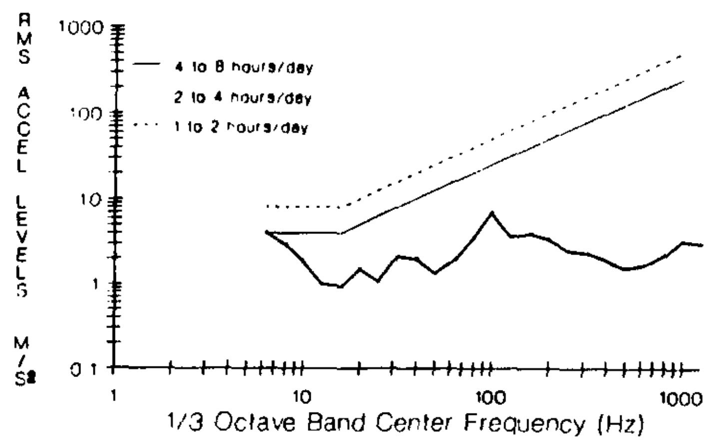
ELECTRIC BOAT
Dresser Cleco 6000 Grinder (a)
Run 3 / x - axis



ELECTRIC BOAT
Dresser Cleco 6000 Grinder (a)
Run 3 / y - axis

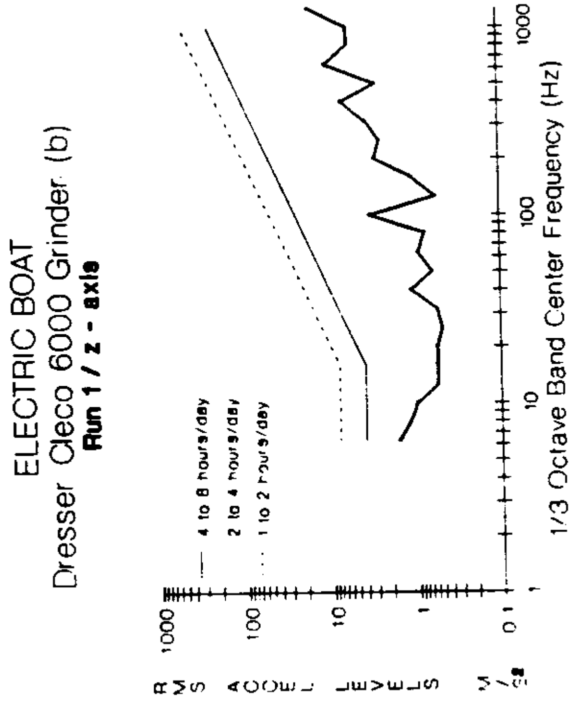


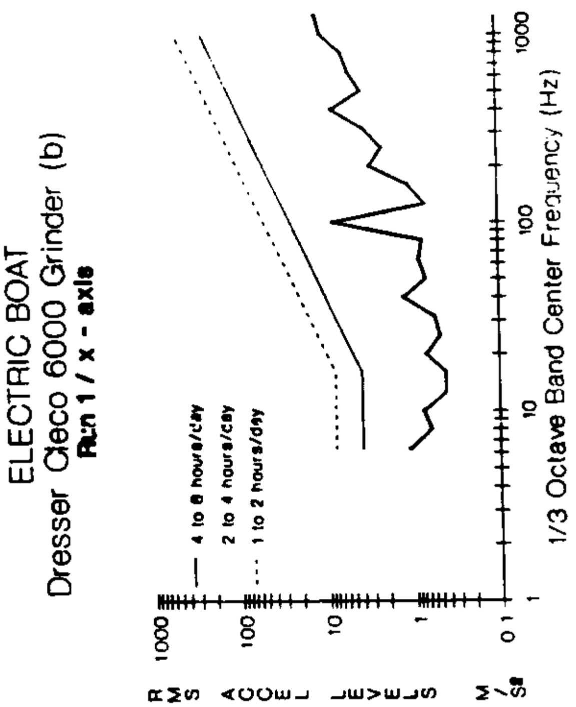
ELECTRIC BOAT
Dresser Cleco 6000 Grinder (a)
Run 3 / z - axis

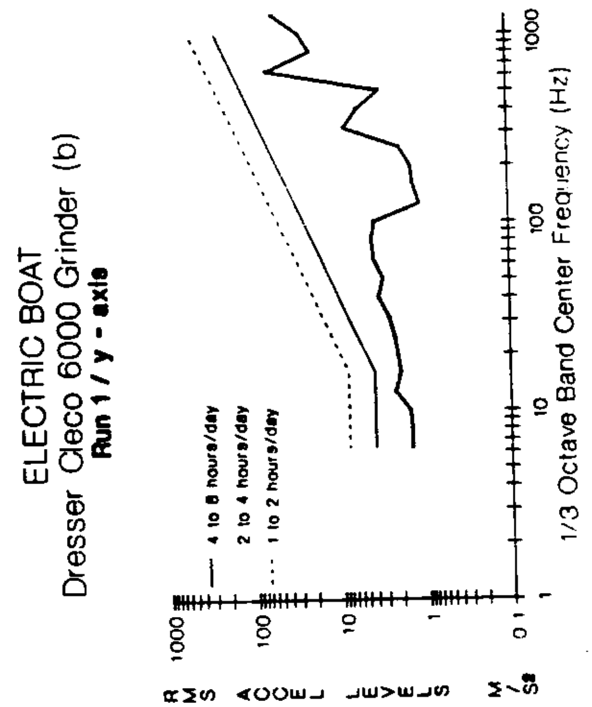


Appendix A

Figure 3

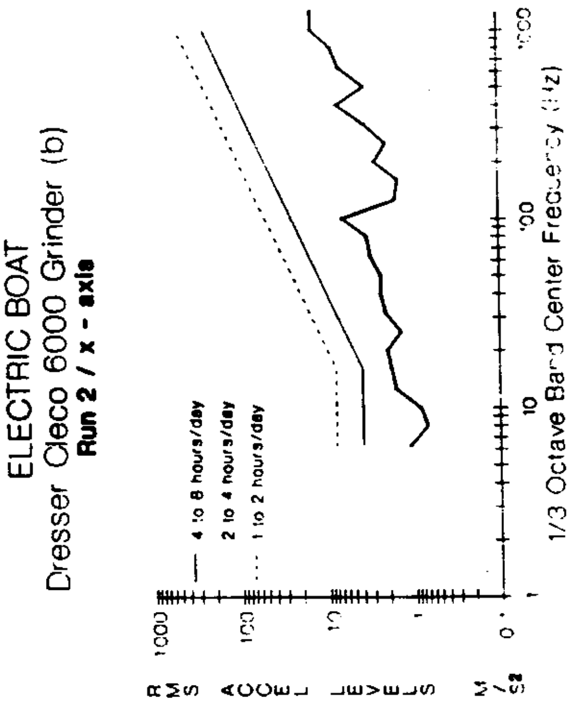


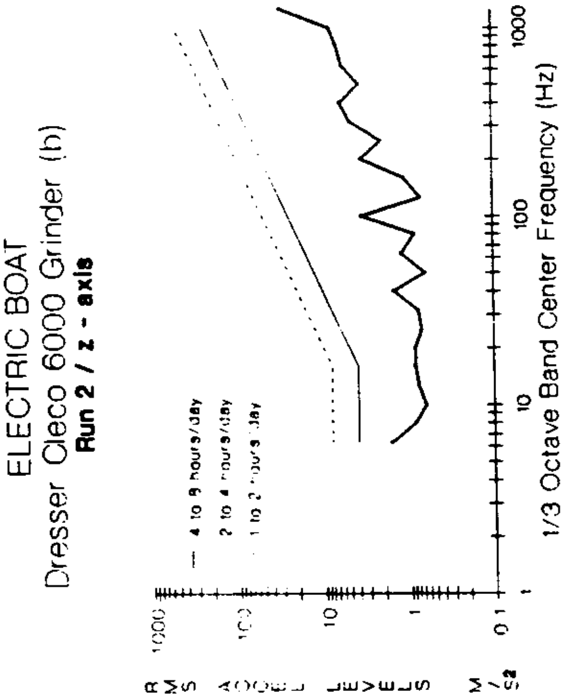


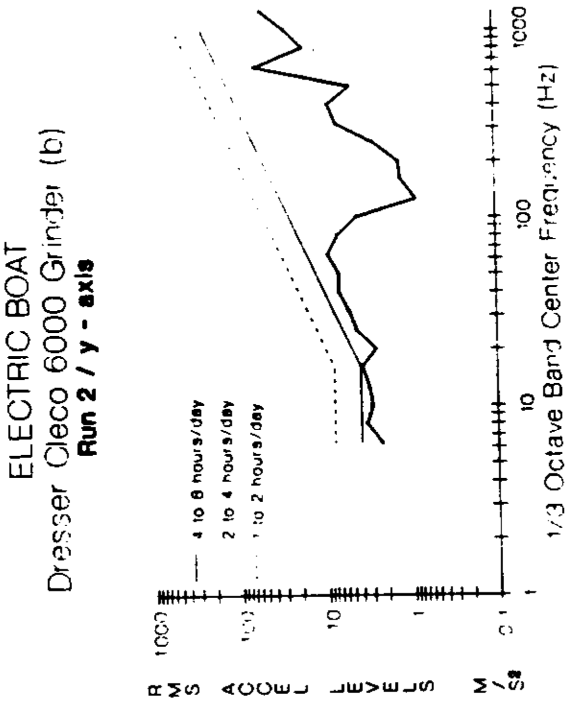


Appendix A

Figure 4



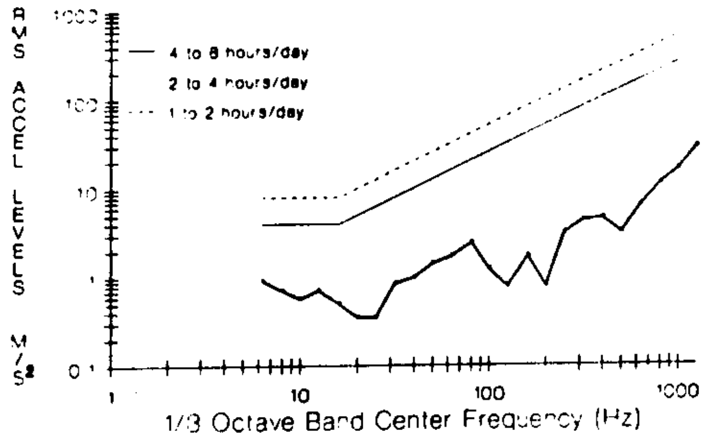




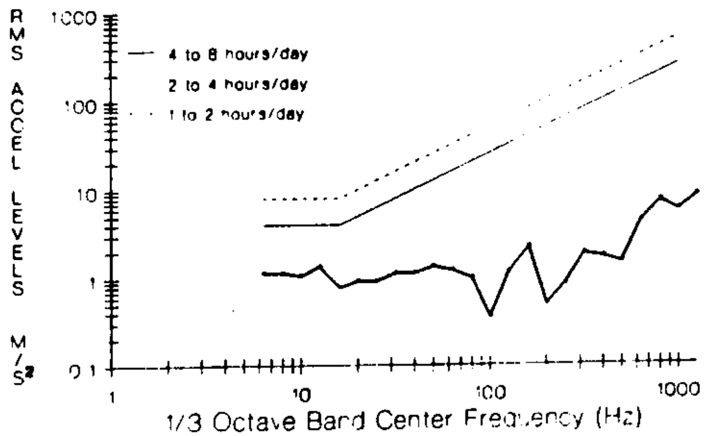
Appendix A

Figure 5

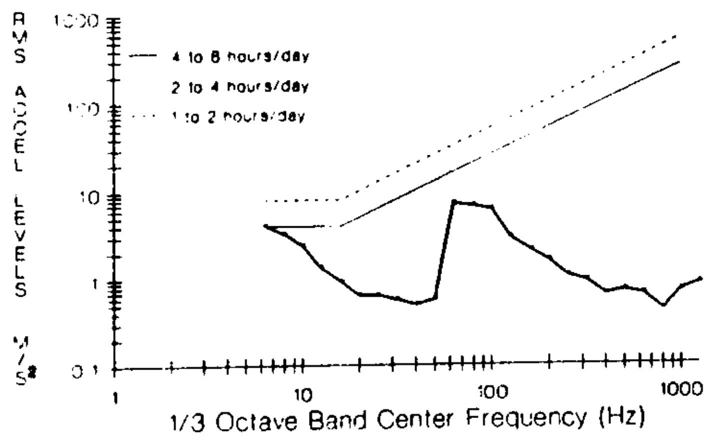
ELECTRIC BOAT
CP 9122 Whirlybird Grinder (a)
Run 5 / x - axis



ELECTRIC BOAT
CP 9122 Whirlybird Grinder (a)
Run 5 / y - axis

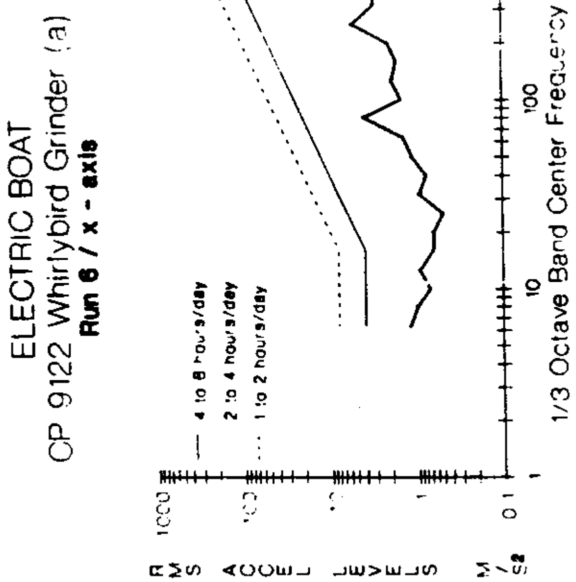


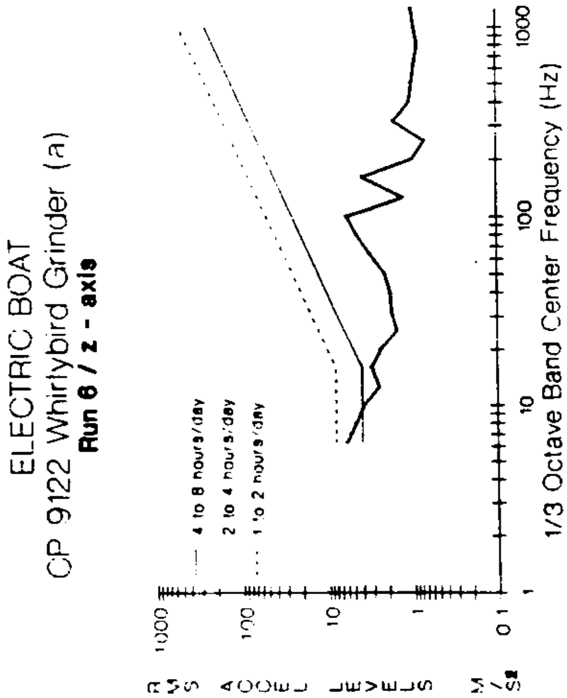
ELECTRIC BOAT
CP 9122 Whirlybird Grinder (a)
Run 5 / z - axis

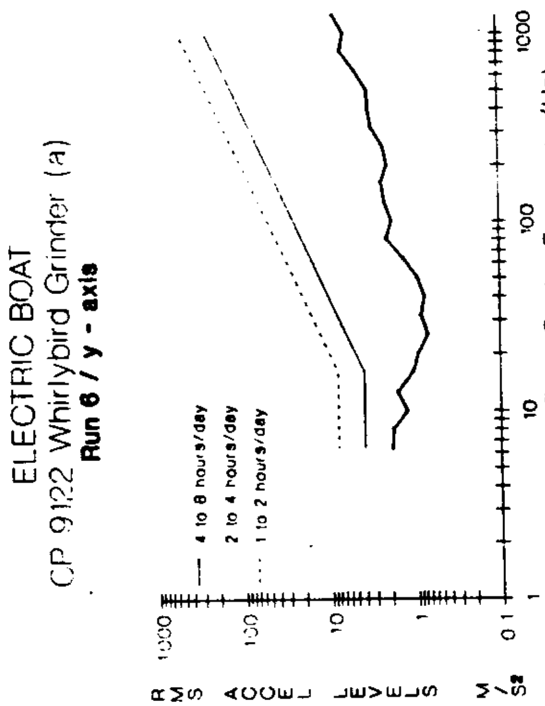


Appendix A

Figure 6



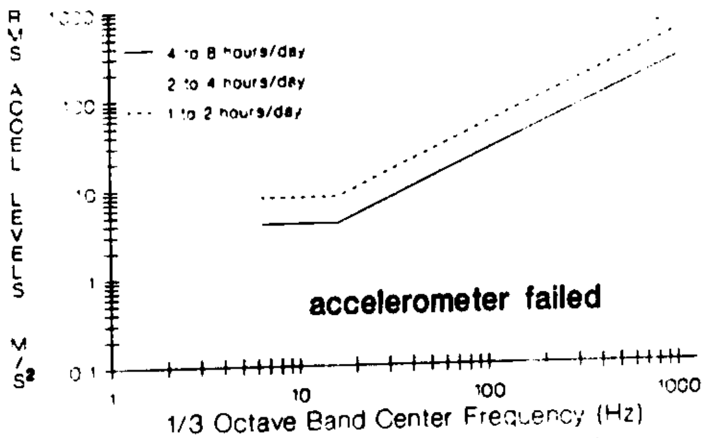




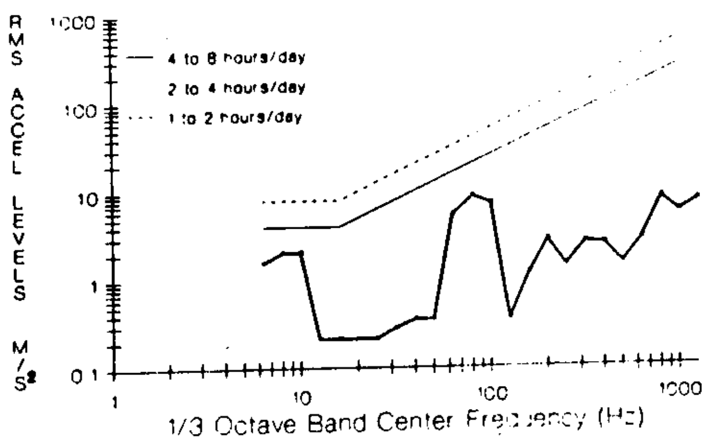
Appendix A

Figure 7

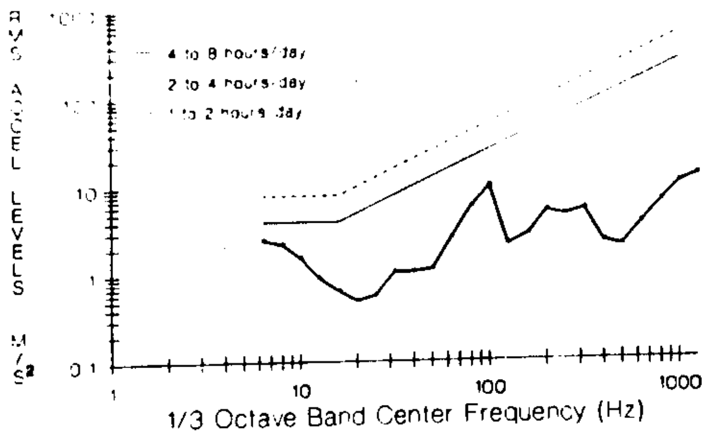
ELECTRIC BOAT
CP 9122 Whirlybird Grinder (b)
Run 2 / x - axis



ELECTRIC BOAT
CP 9122 Whirlybird Grinder (b)
Run 2 / y - axis



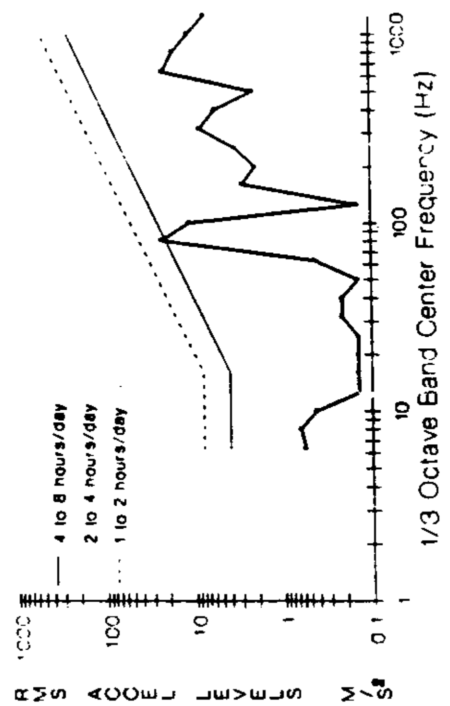
ELECTRIC BOAT
CP 9122 Whirlybird Grinder (b)
Run 2 / z - axis



Appendix A

Figure 8

ELECTRIC BOAT
CP 9122 Whirlybird Grinder (b)
Run 4 / x - axis



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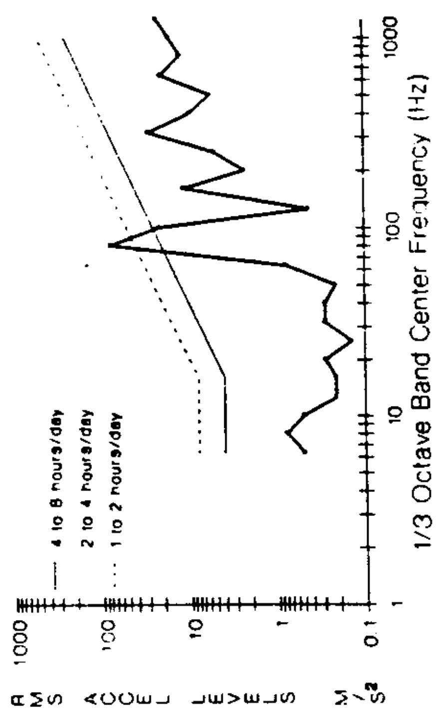
CP 9122 Whirlybird Grinder (b)
Run 4 / y - axis



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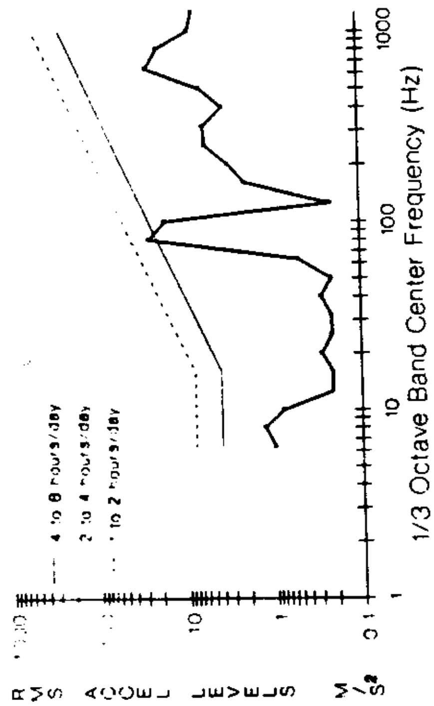
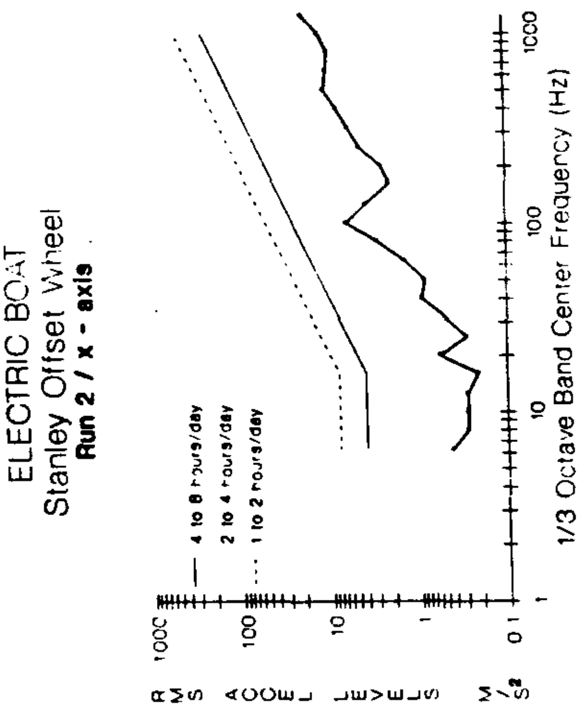
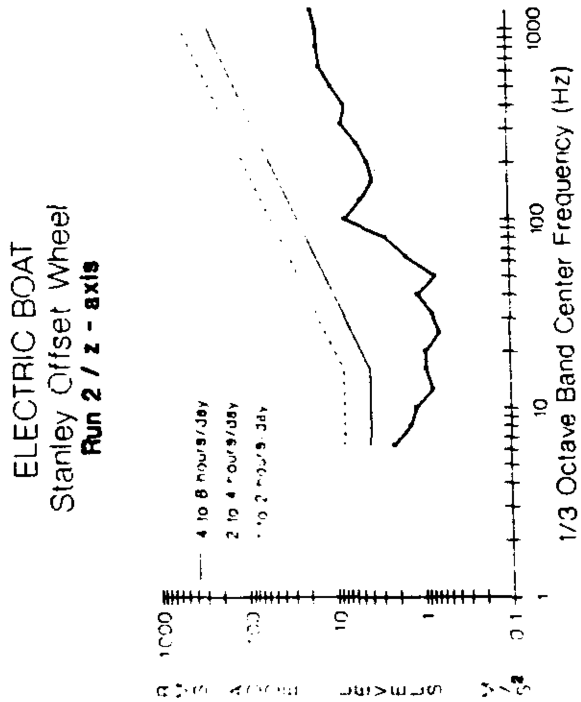
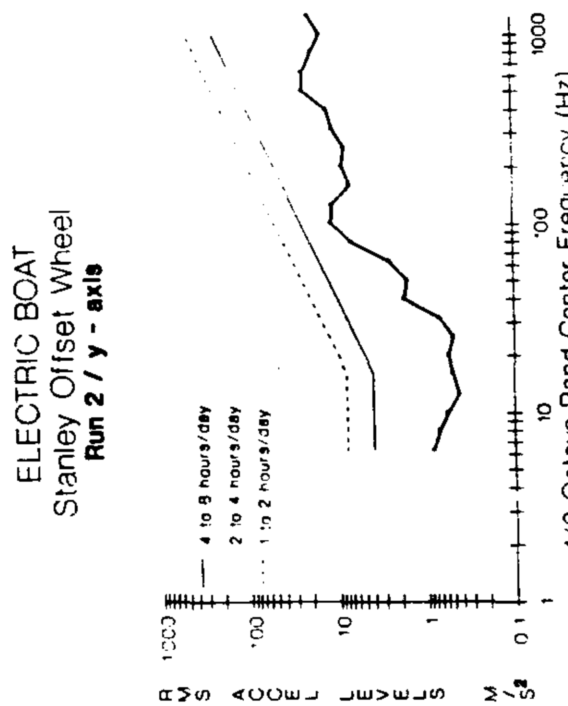


Appendix A

Figure 9

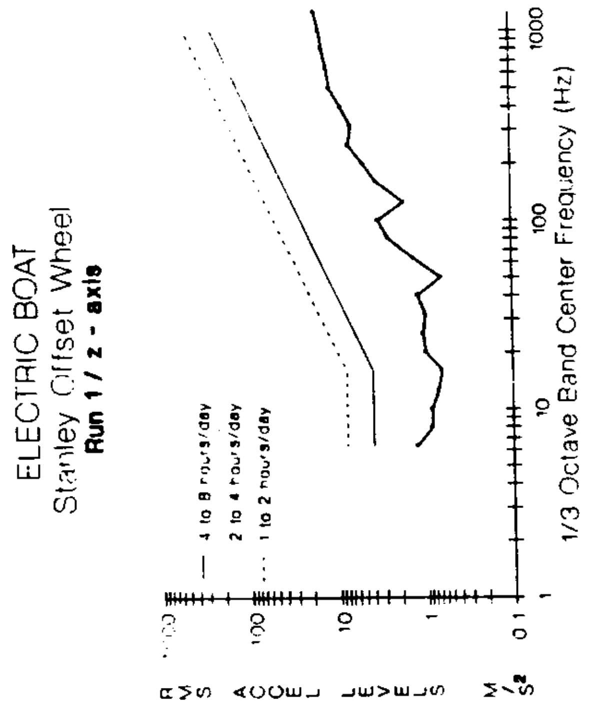


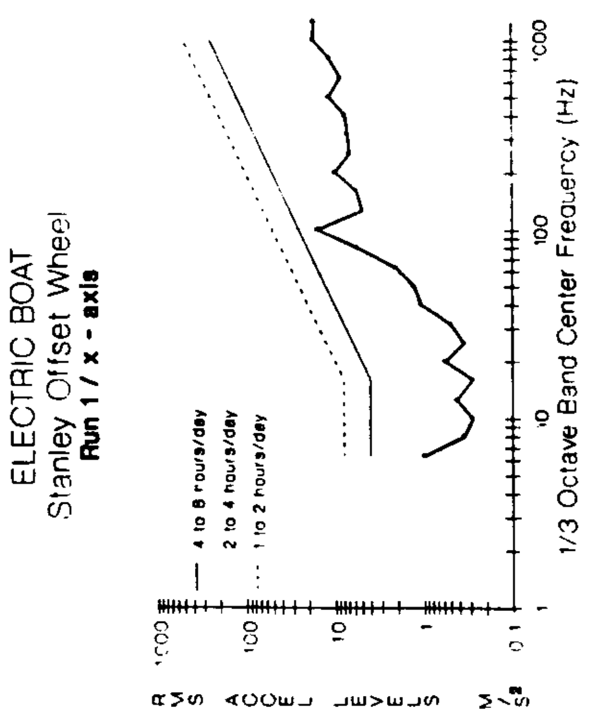


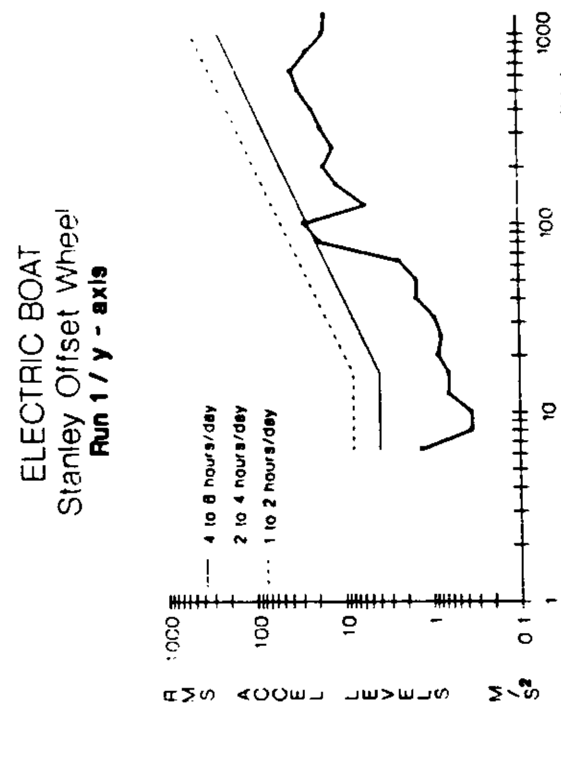


Appendix A

Figure 10



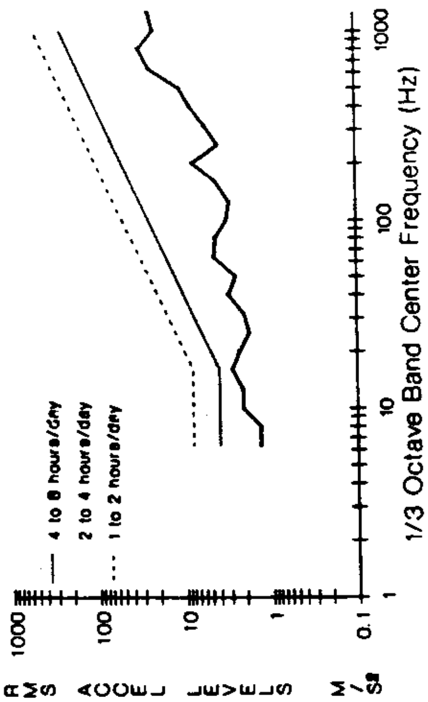




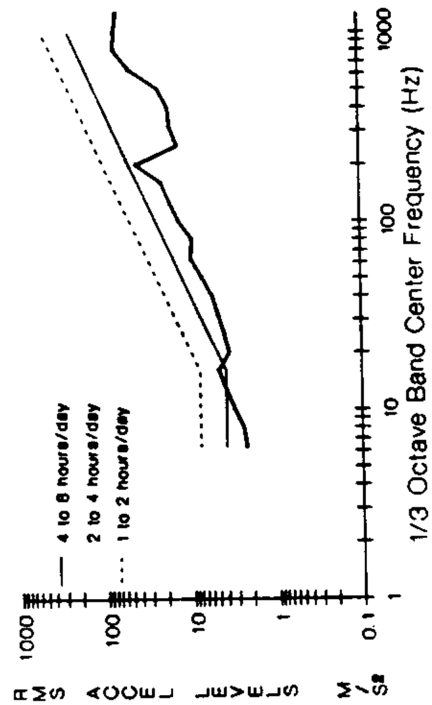
Appendix A

Figure 11

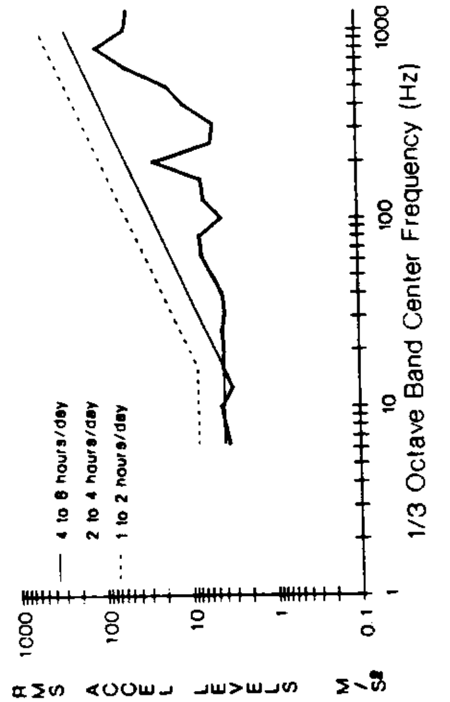
ELECTRIC BOAT
CP 9113 Large Straight Burr
Run 1 / x - axis



ELECTRIC BOAT
CP 9113 Large Straight Burr
Run 1 / y - axis

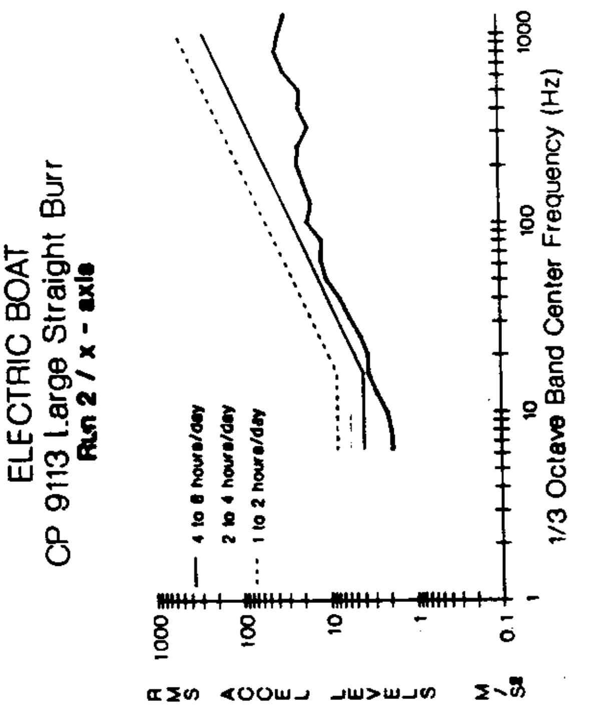


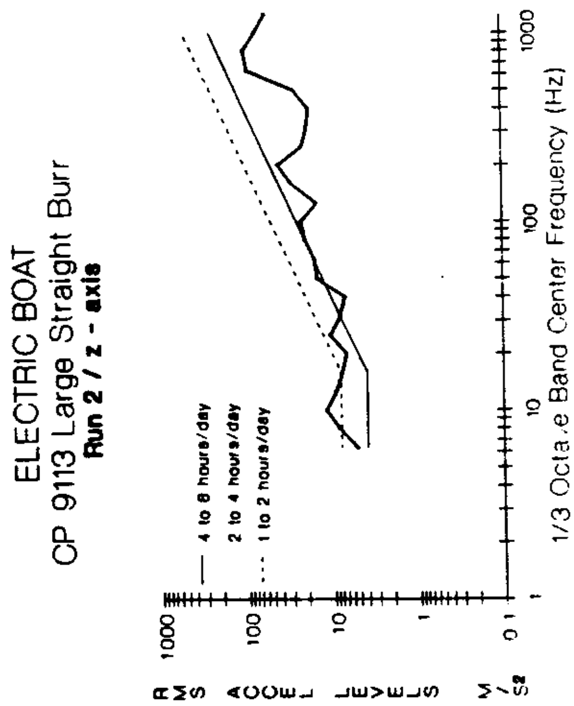
ELECTRIC BOAT
CP 9113 Large Straight Burr
Run 1 / z - axis



Appendix A

Figure 12





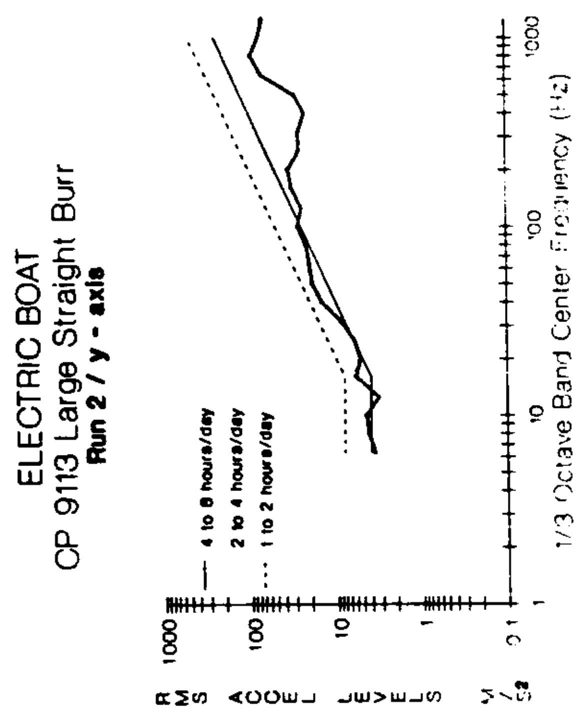


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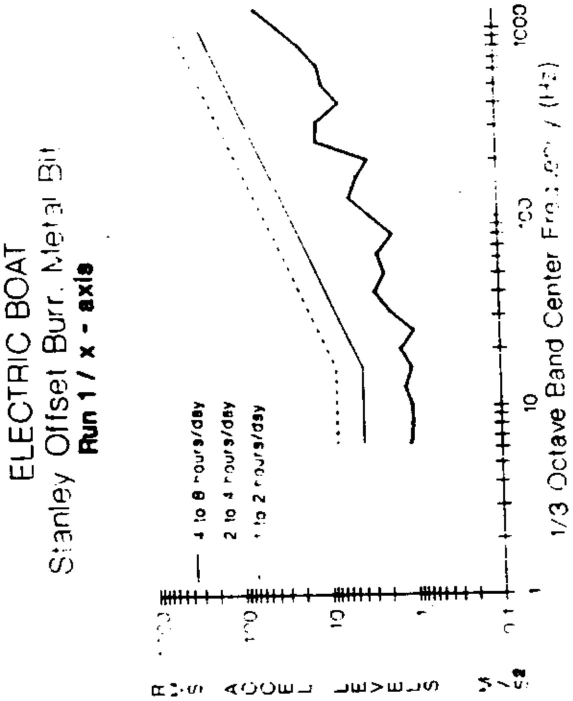
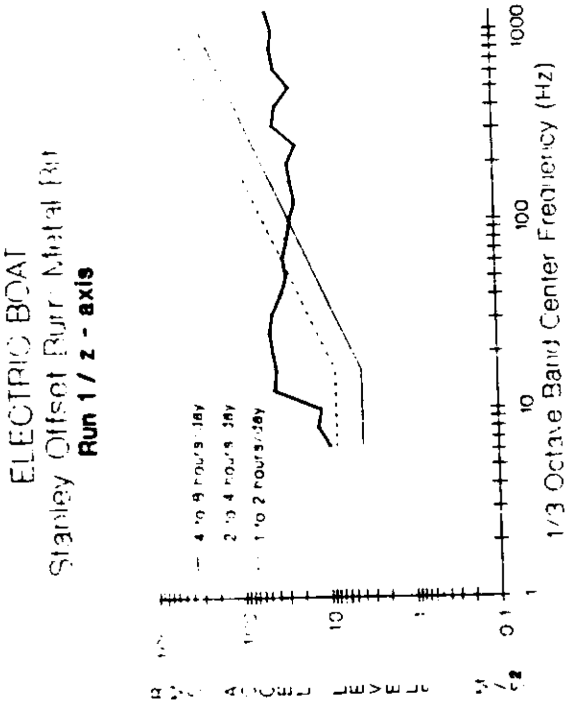
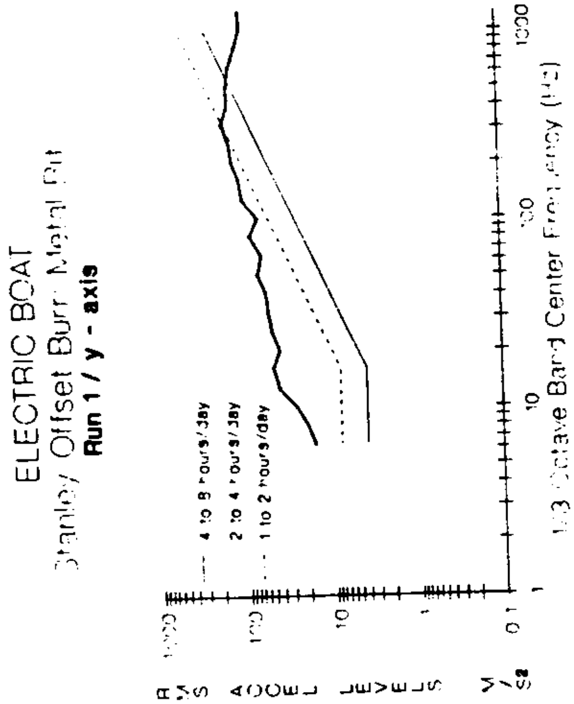
Figure 13

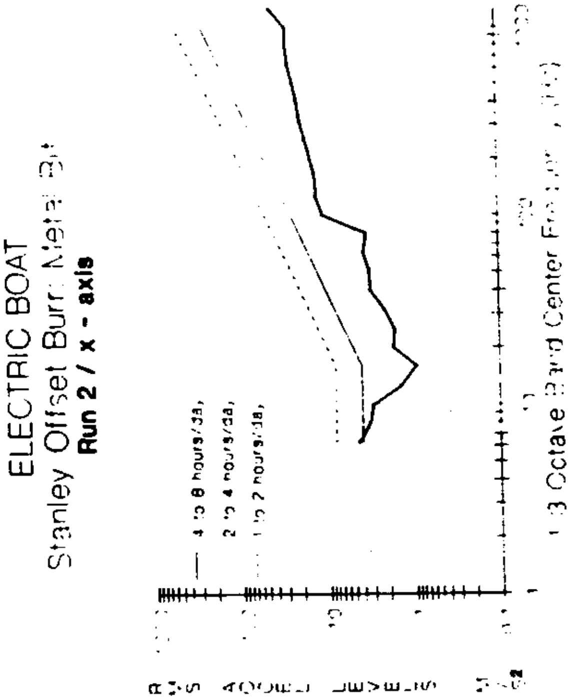


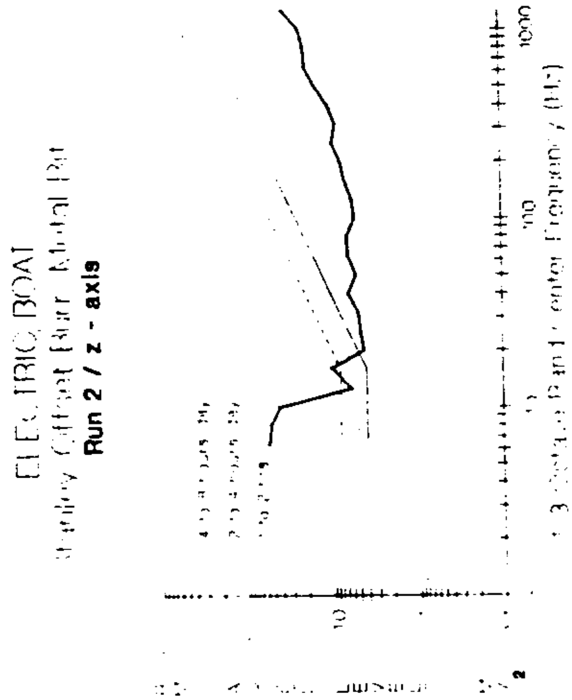


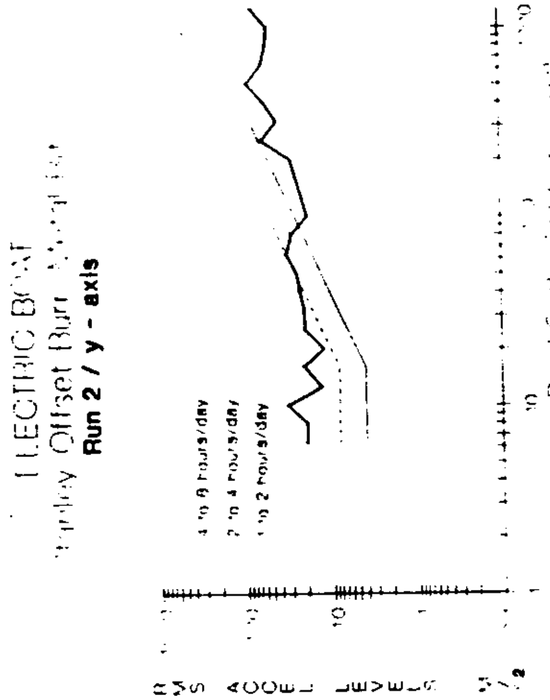


Appendix A

Figure 14

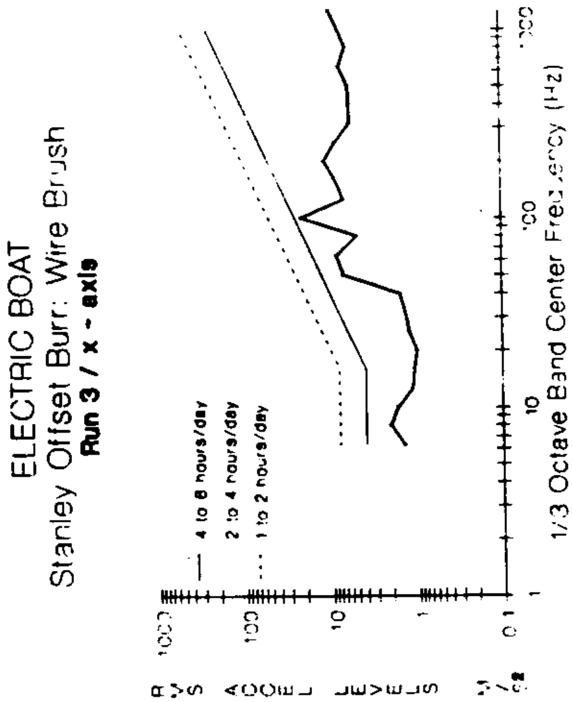


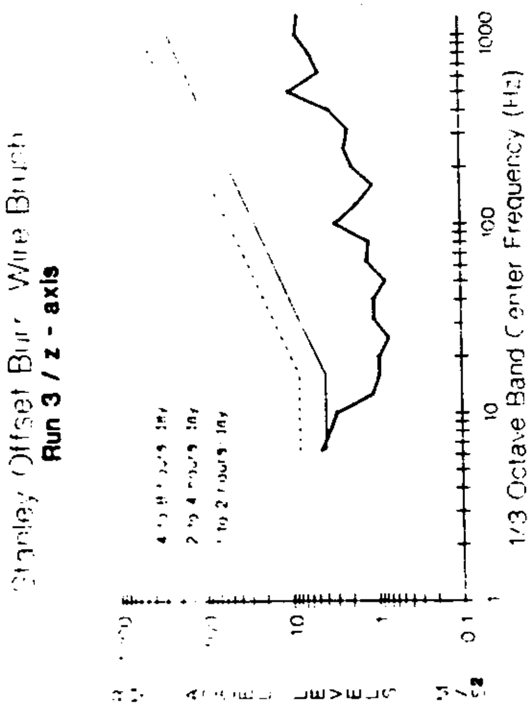


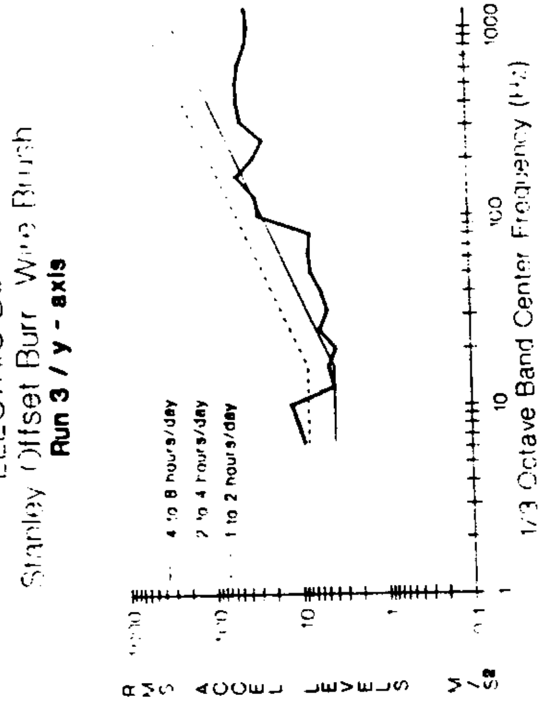


Appendix A

Figure 15

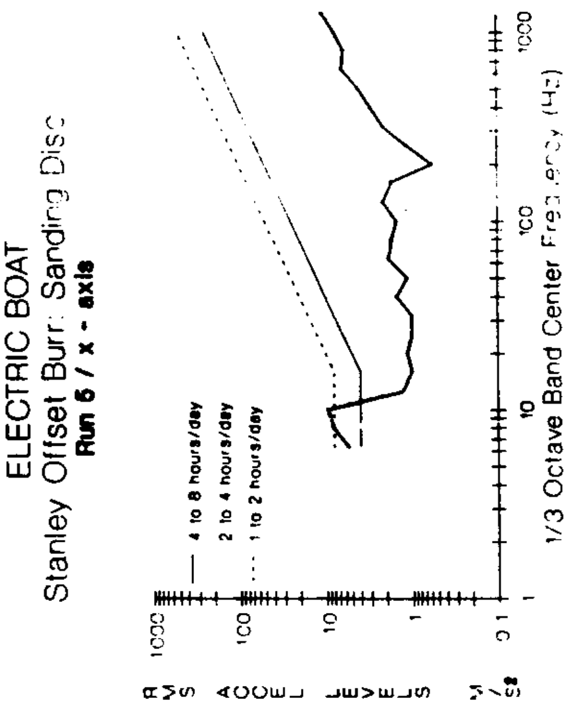


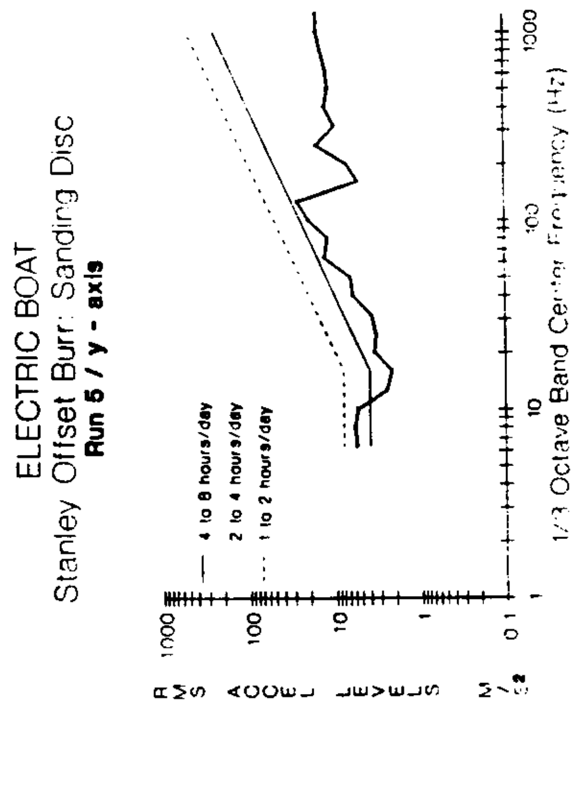


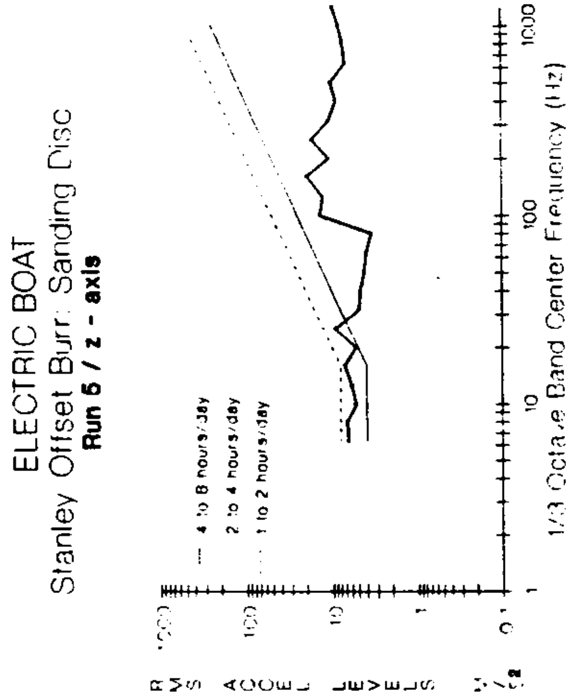


Appendix A

Figure 16

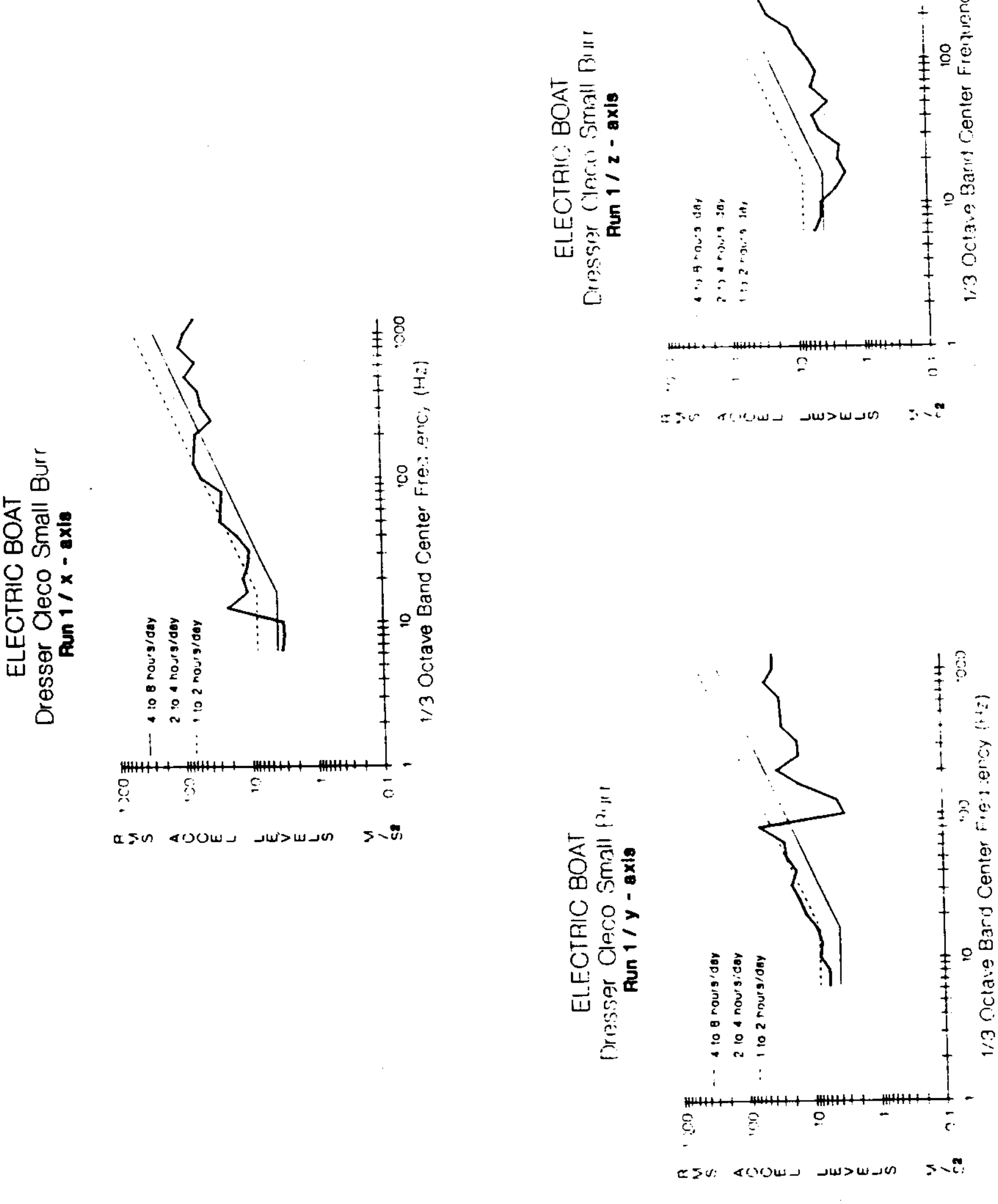






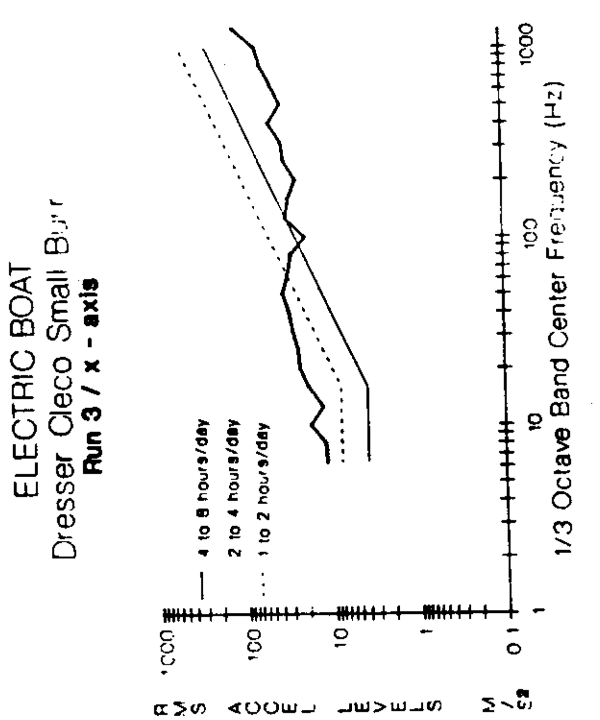
Appendix A

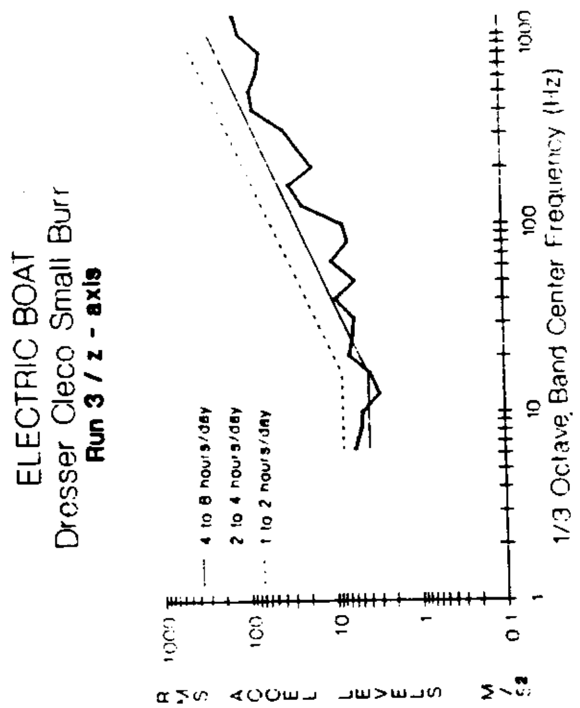
Figure 17

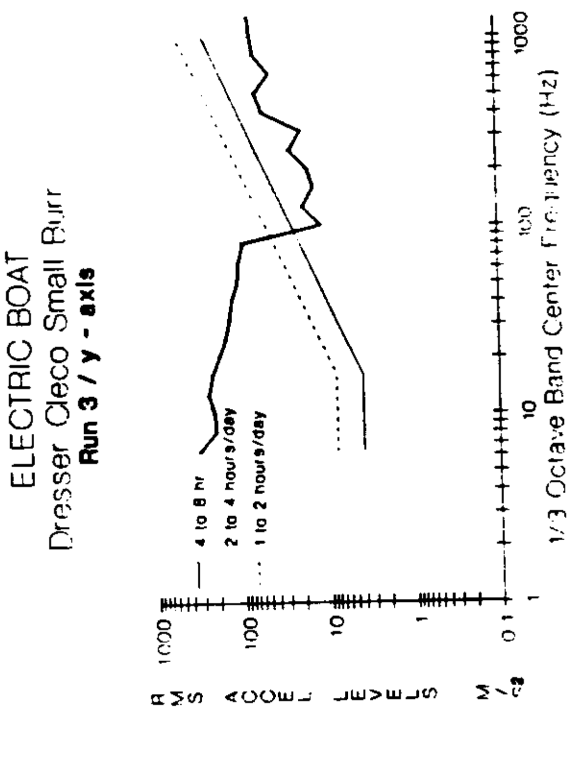


Appendix A

Figure 18

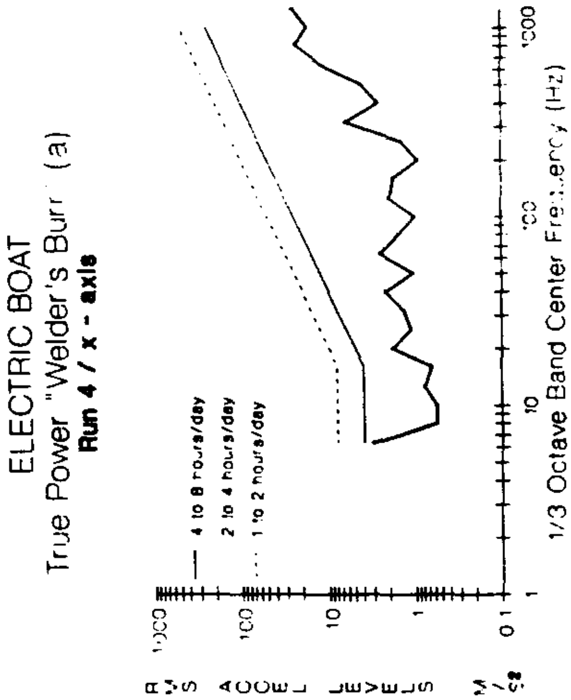


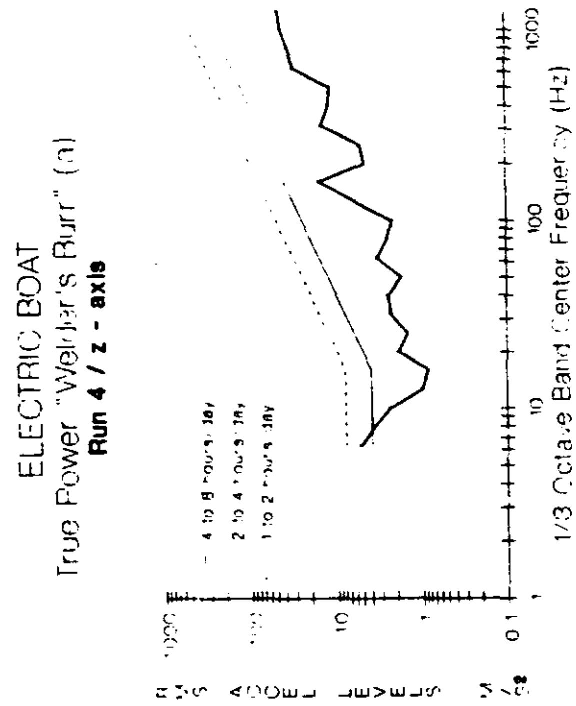


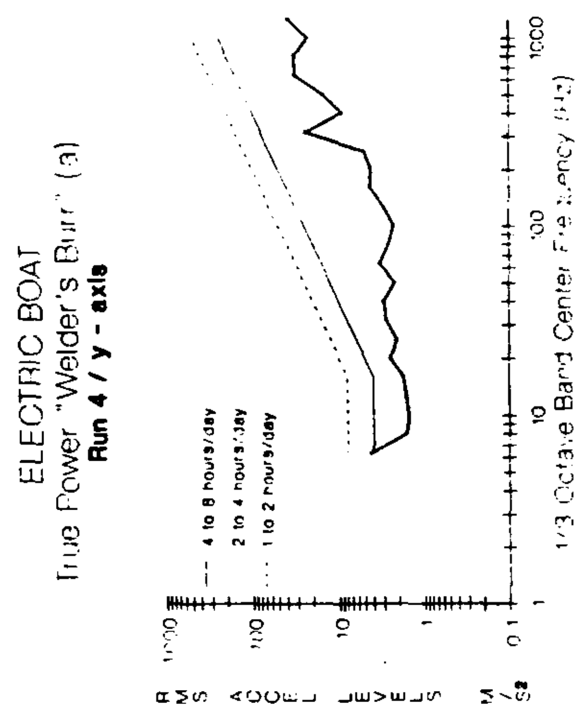


Appendix A

Figure 19

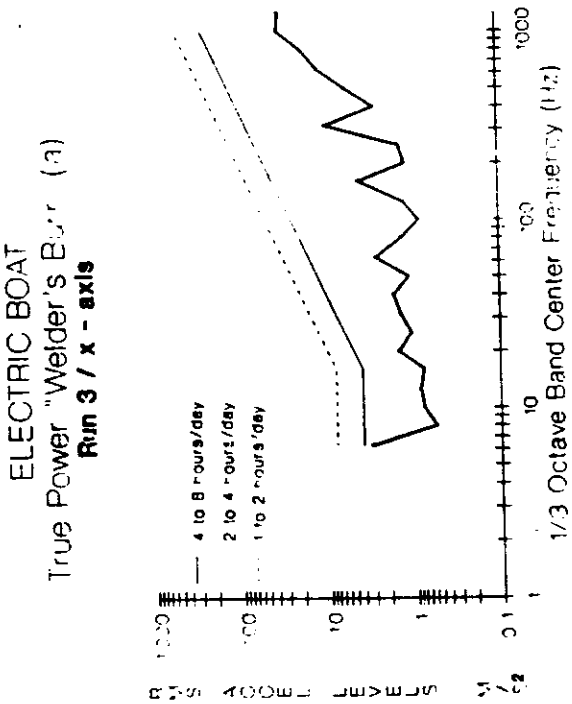


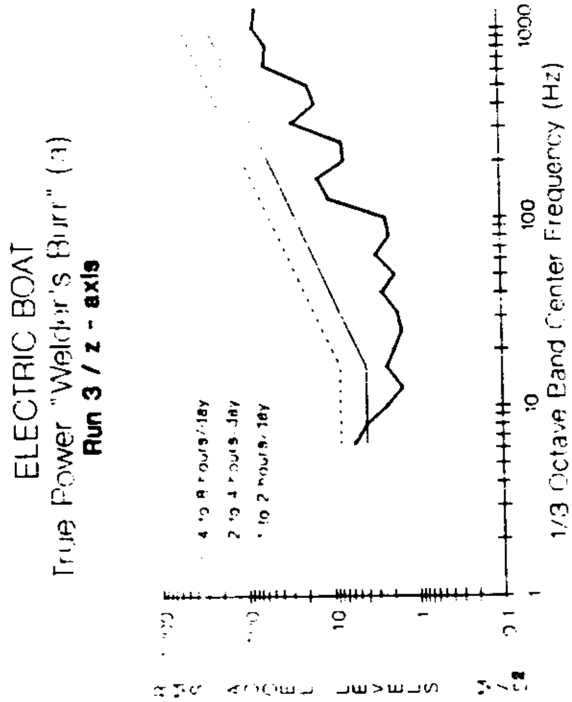


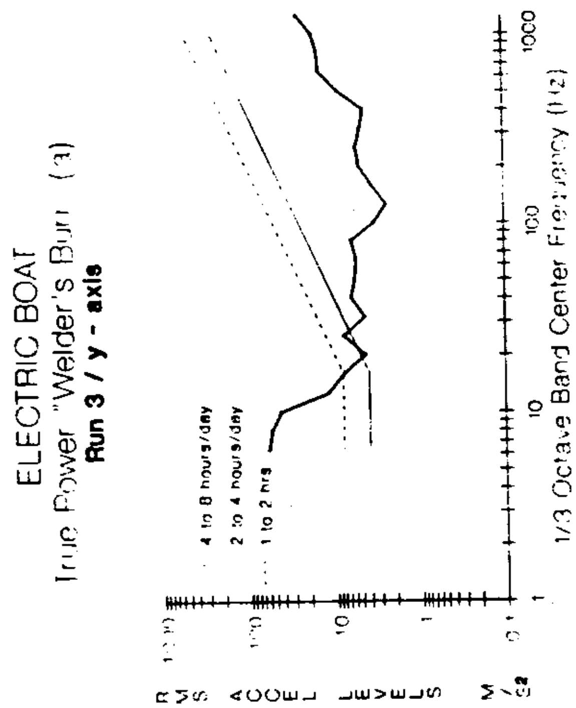


Appendix A

Figure 20

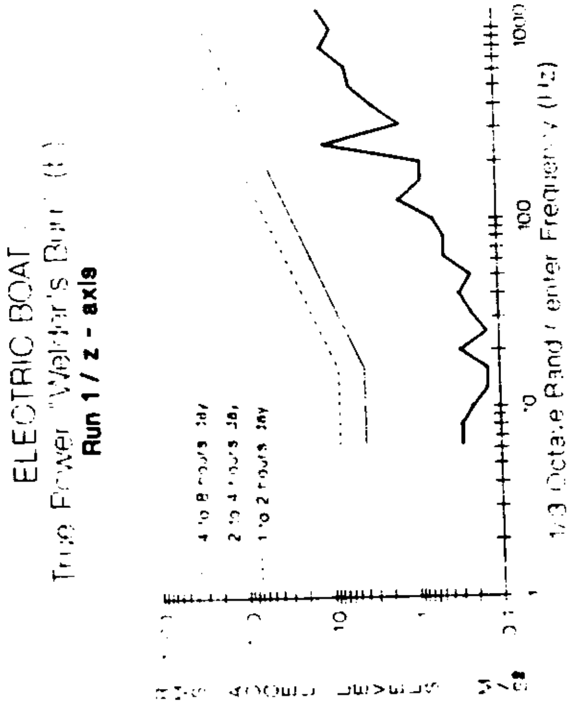


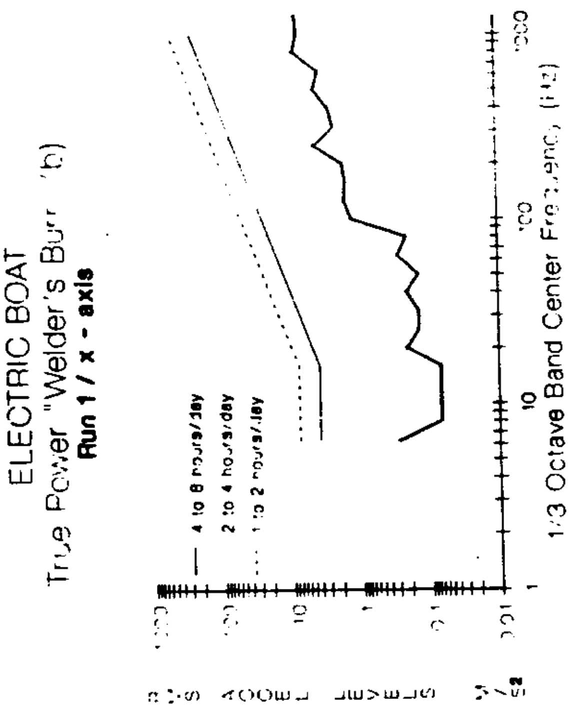


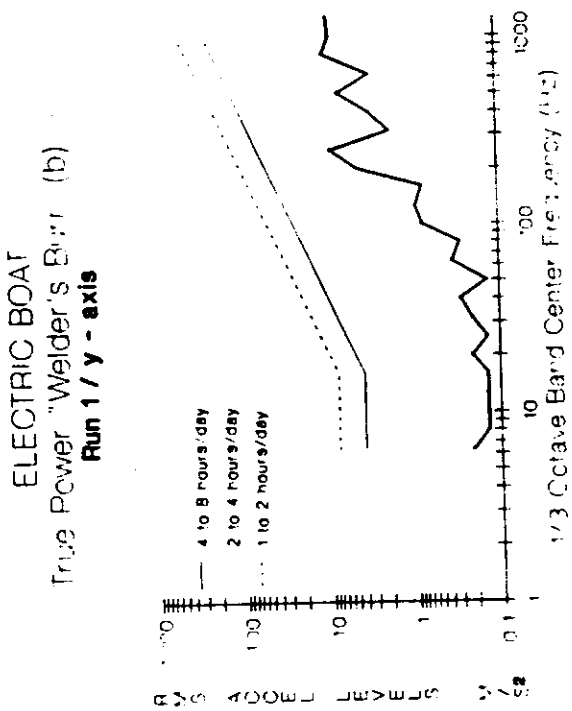


Appendix A

Figure 21

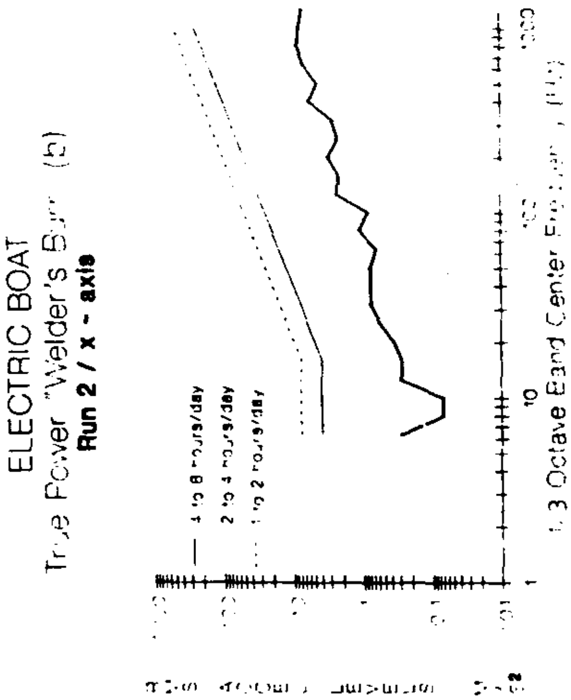


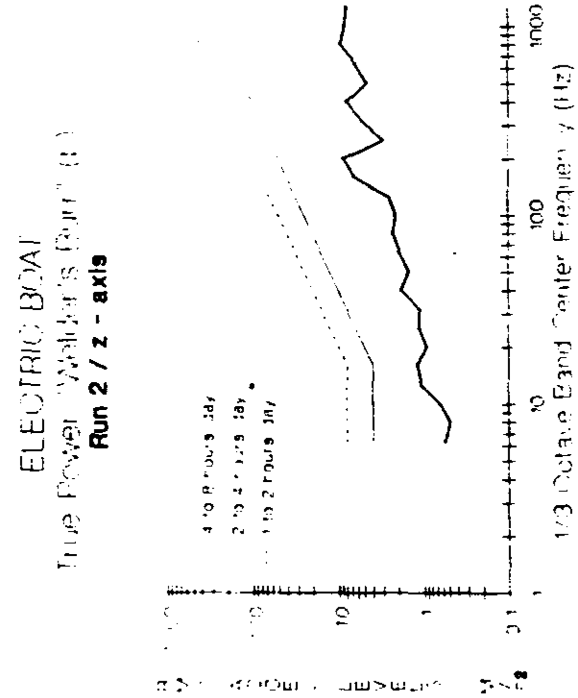


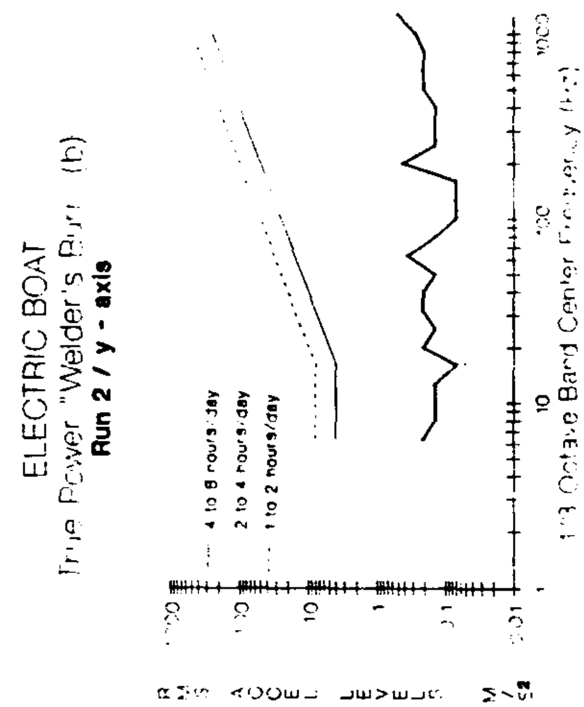


Appendix A

Figure 22

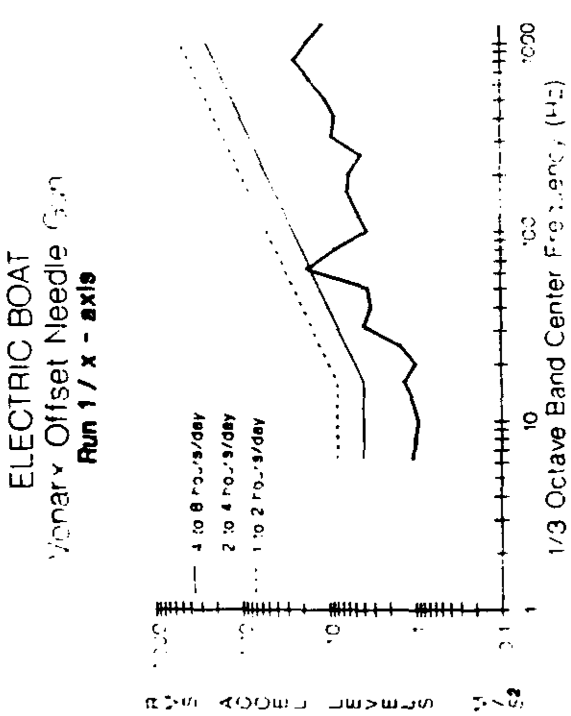


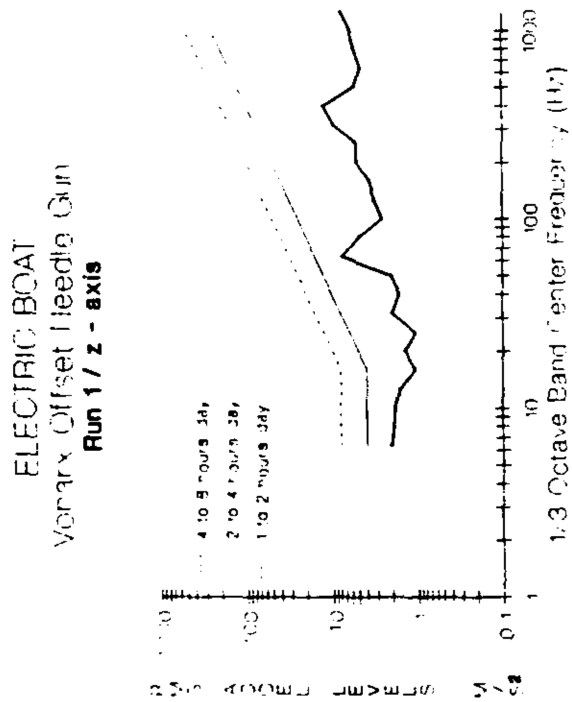


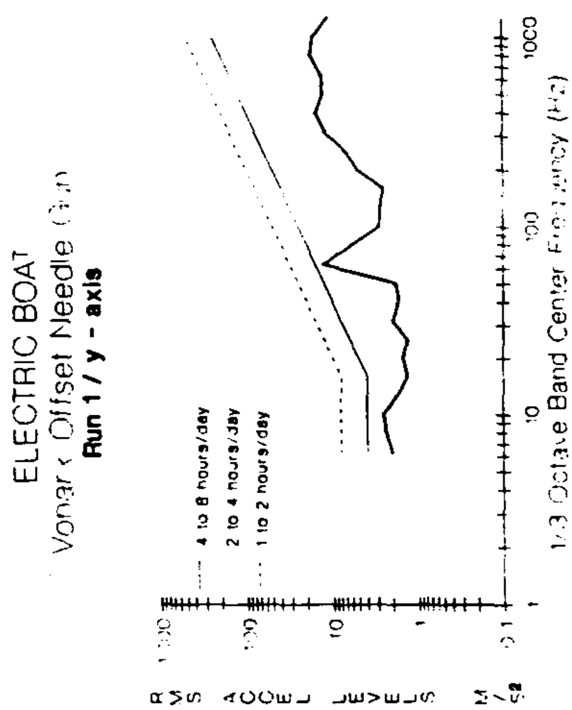


Appendix A

Figure 23

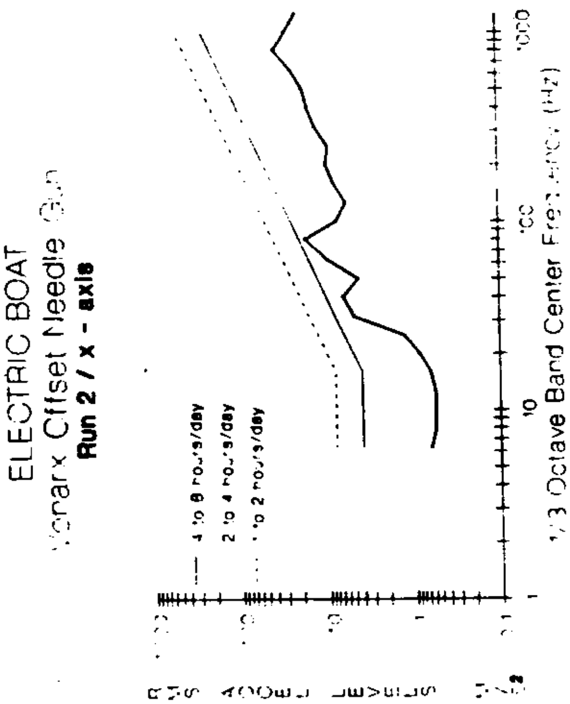


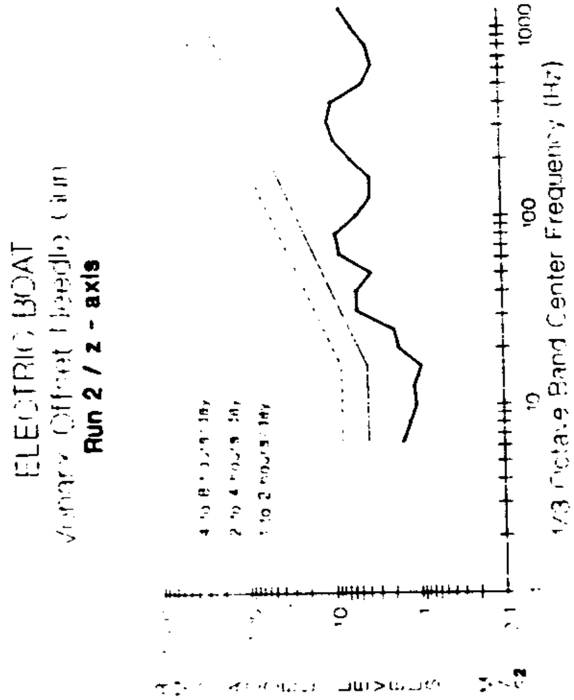


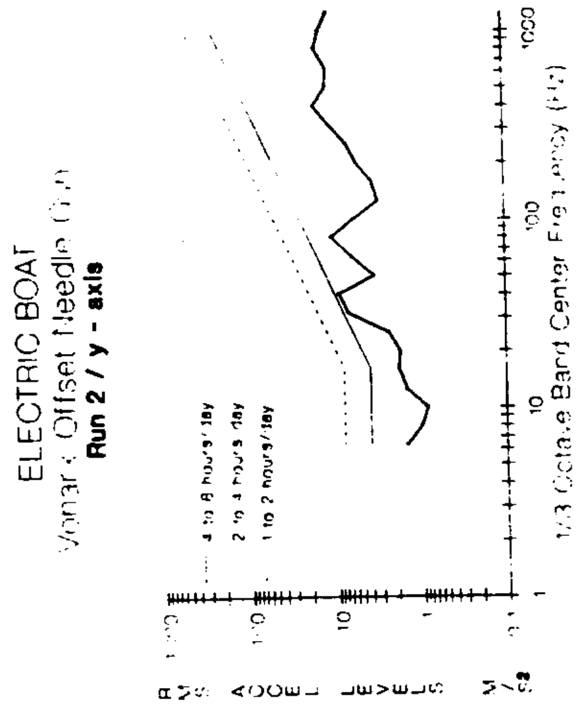


Appendix A

Figure 24

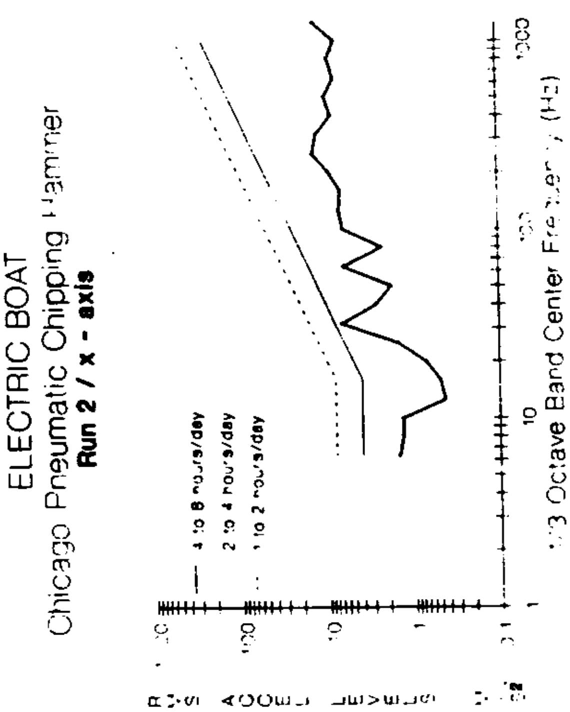


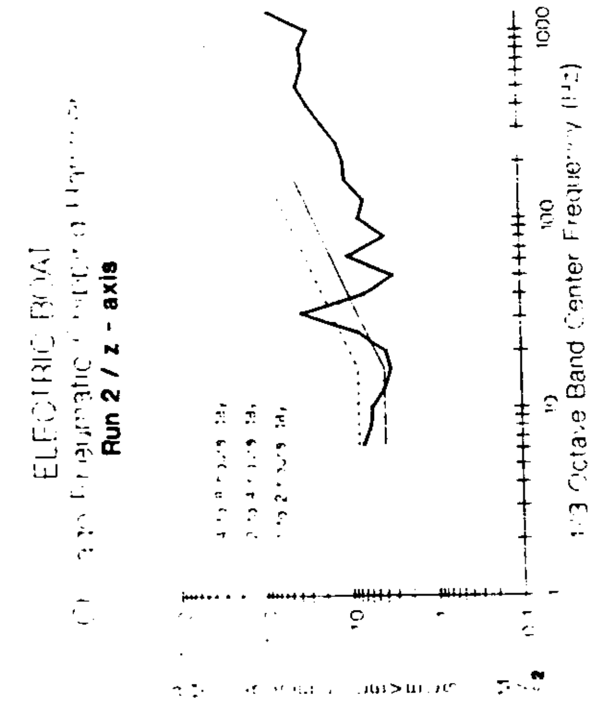




Appendix A

Figure 25





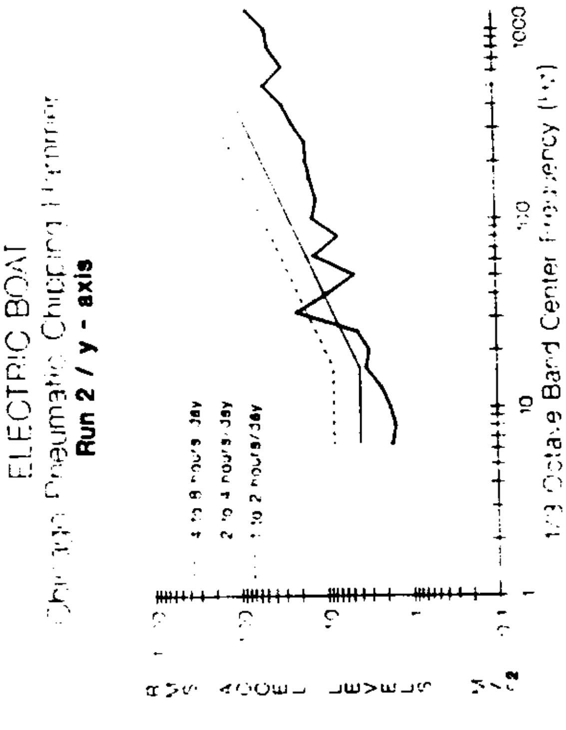


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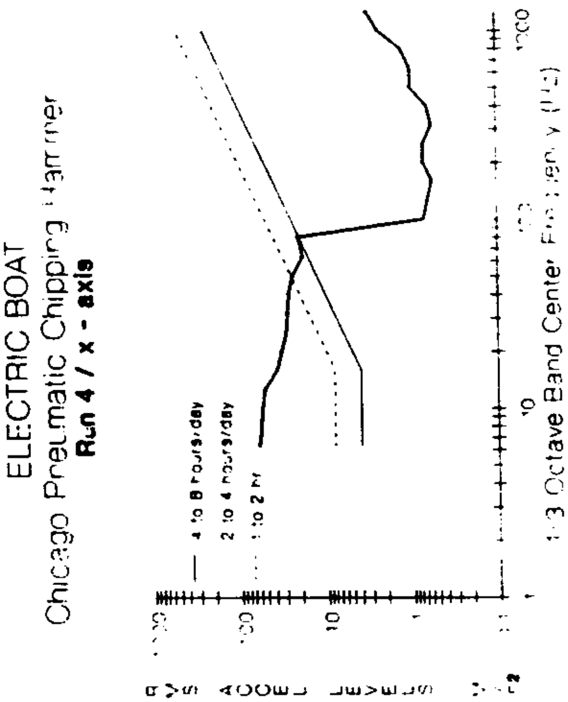
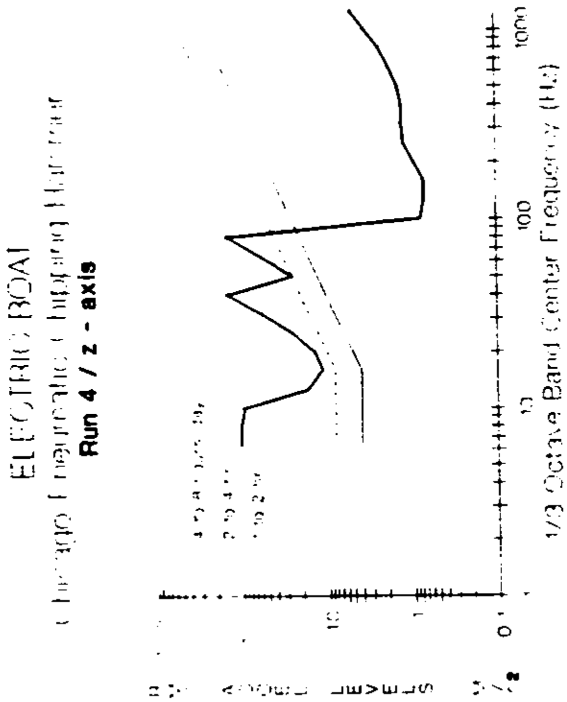
Figure 26





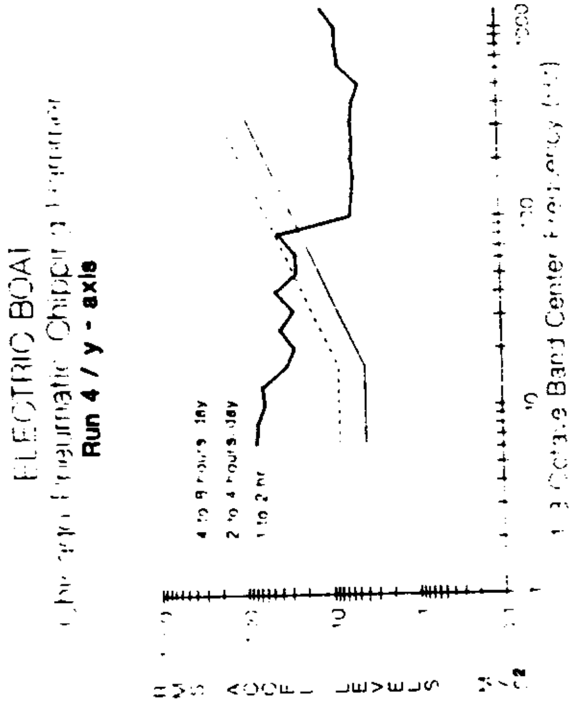


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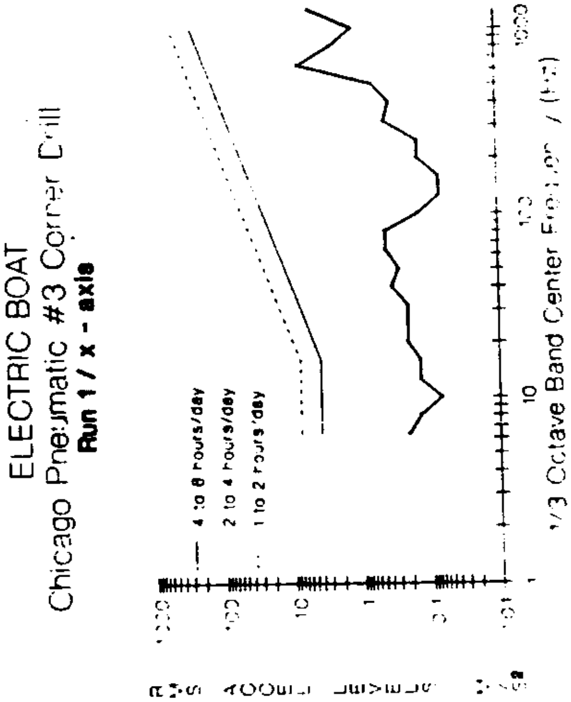
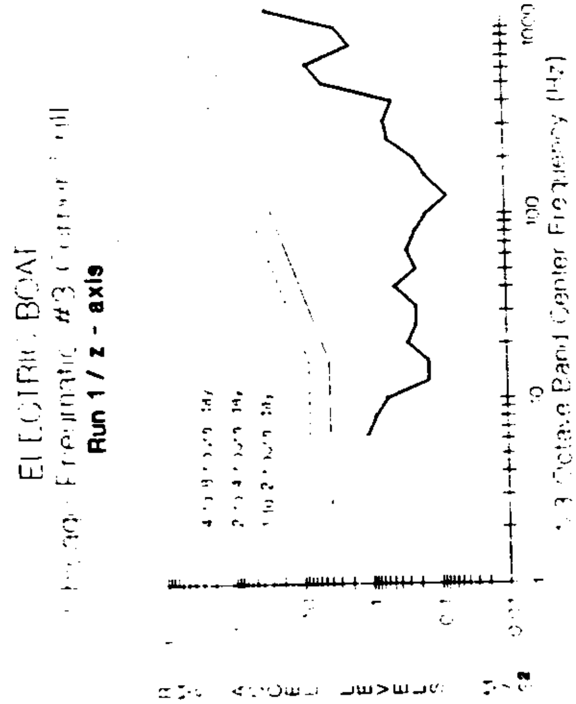
Figure 27





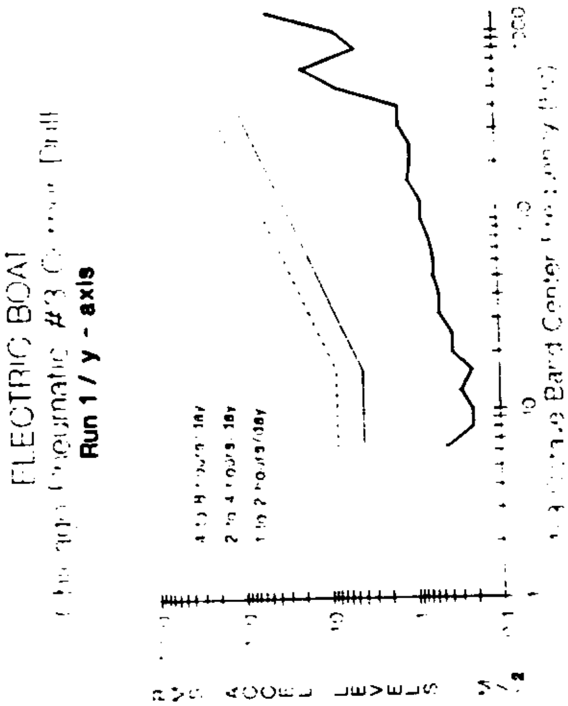


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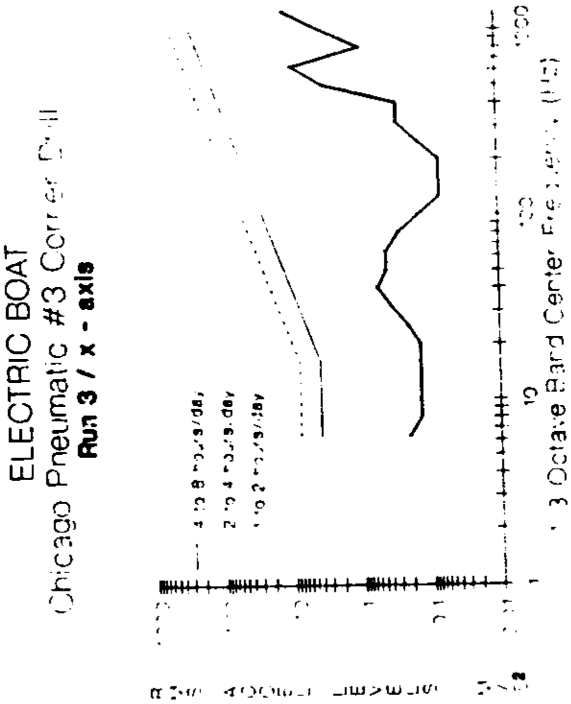
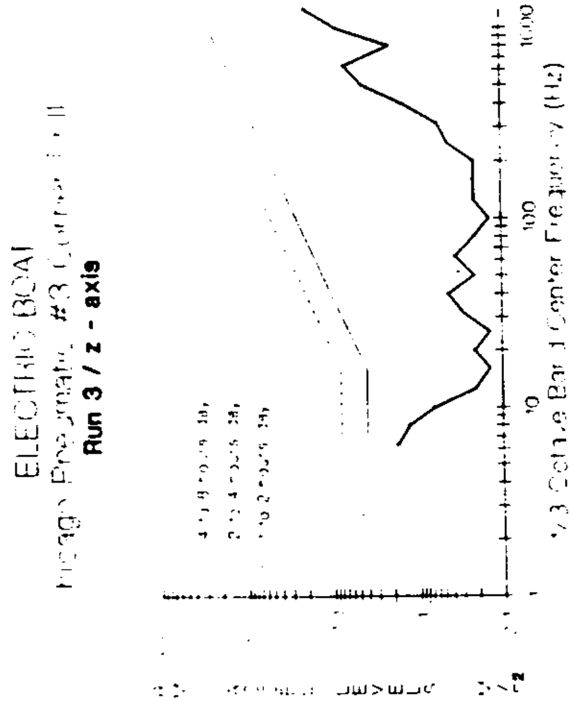
Figure 28





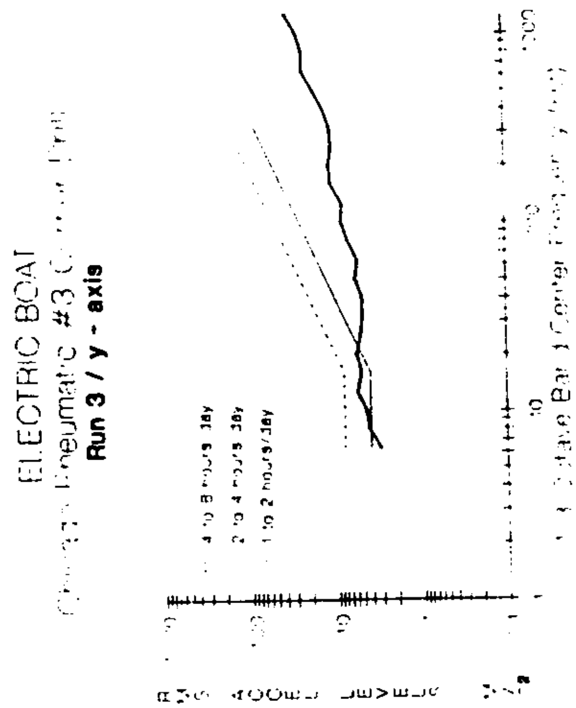


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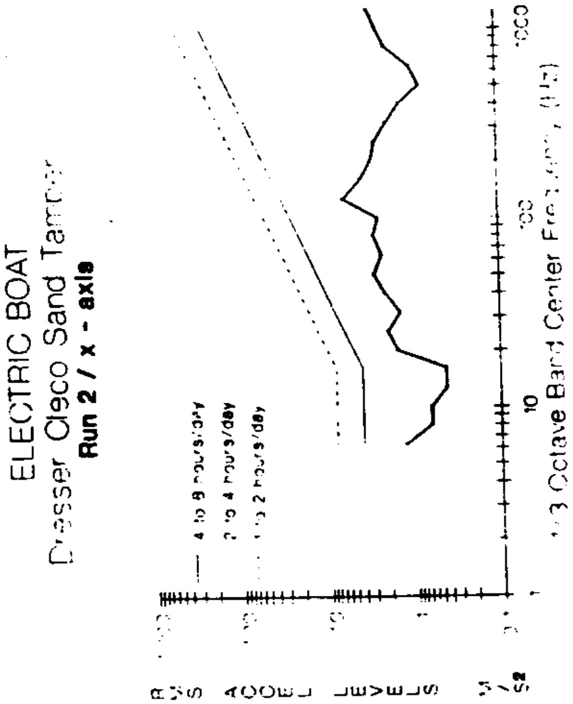
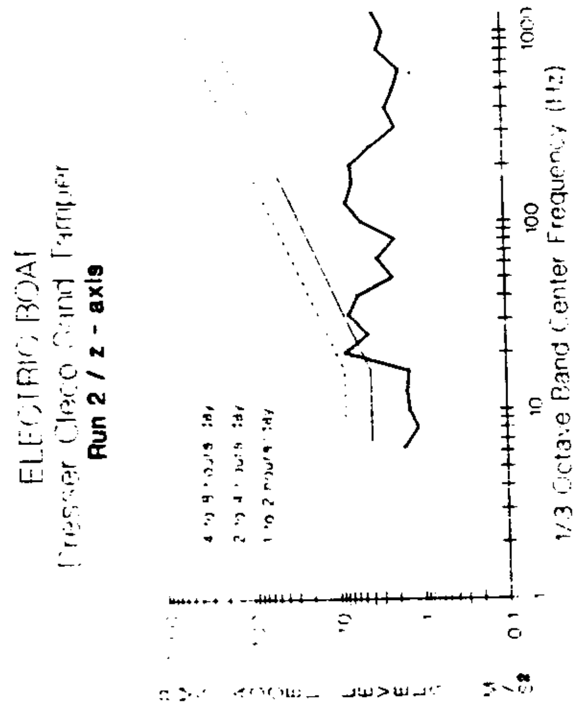
Figure 29





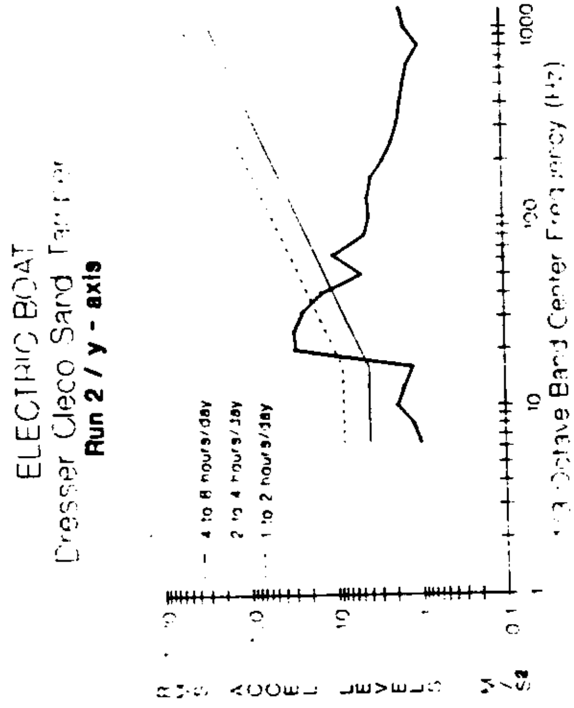


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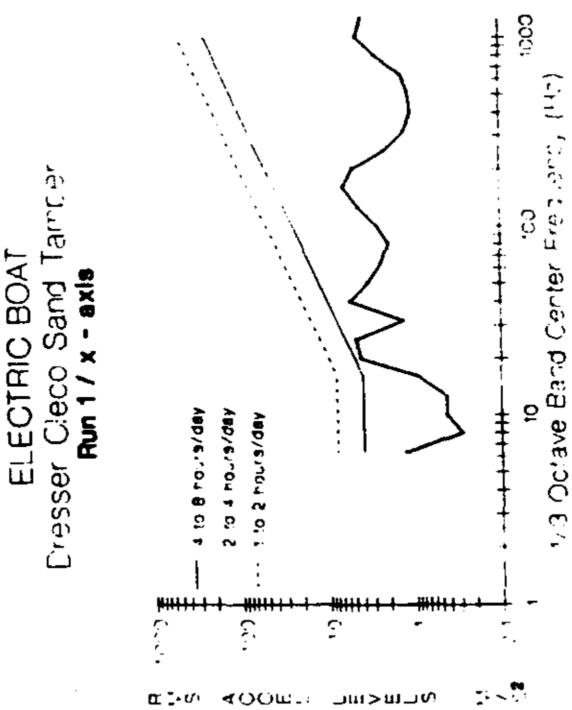
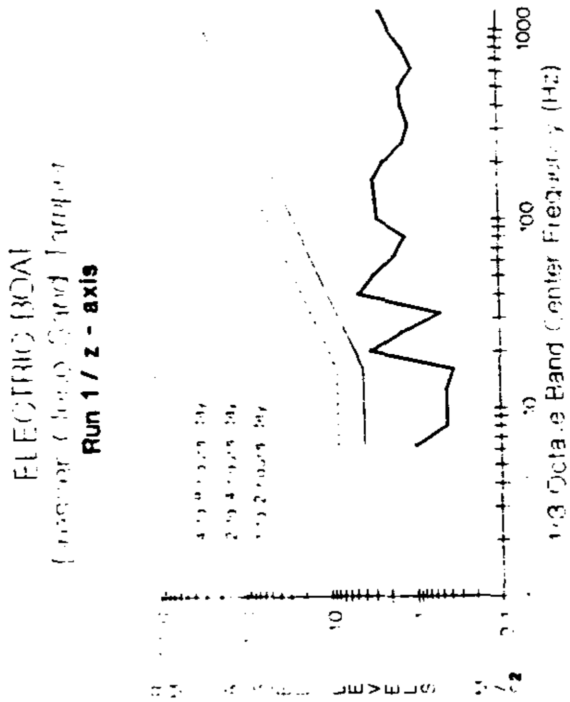
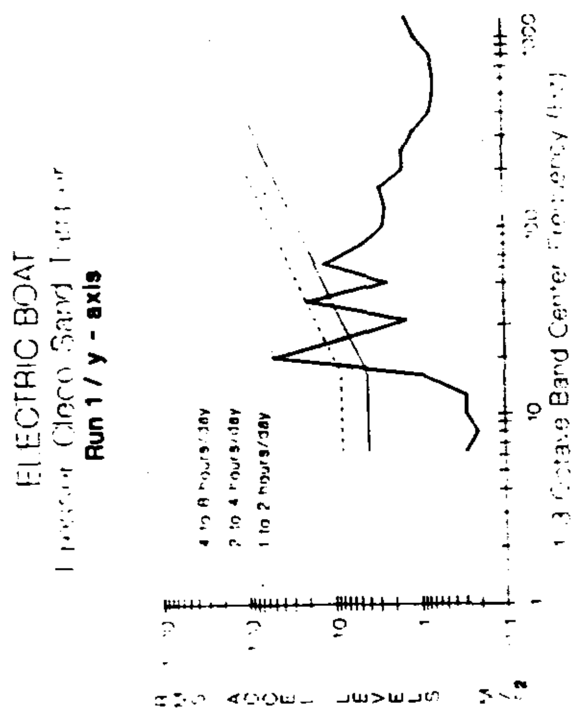
Figure 30







APPENDIX B

CHAPTER 7

CRITERIA for a RECOMMENDED STANDARD

OCCUPATIONAL EXPOSURE to HAND-ARM VIBRATION

NIOSH PUBLICATION No. 89-106, SEPTEMBER, 1989

VII. METHODS FOR WORKER PROTECTION

The major emphasis for worker protection from HAVS should be directed toward prevention. After the disorder has progressed beyond Stage 2 of the Stockholm classification, procedures designed to reverse the process are usually not effective. Because the development of HAVS is dose related, effective control procedures should be directed to (1) reducing the intensity (acceleration) of the vibration, (2) reducing the exposure duration, (3) identifying the early signs and symptoms, and (4) identifying vibration-sensitive individuals. Control strategies include (1) exposure monitoring, (2) engineering controls, (3) work practices, (4) ergonomic considerations, (5) protective clothing and equipment, (6) worker training, and (7) medical monitoring.

A. EXPOSURE MONITORING

Any effective control procedure requires objective data on the degree of hazard to which the worker is exposed. For the use of vibrating tools, these needed data are the vibration acceleration expressed in m/sec^2 rms measured in the three basicentric coordinates (or the coordinate with the highest acceleration), and the time in minutes per day that the tool is actually in use (scheduled or nonscheduled rest breaks are not included as exposure time). The acceleration measurements should be made as described in Chapter III, B.1 and B.2.

B. ENGINEERING CONTROLS

The major engineering approaches to the elimination or reduction of the vibration acceleration level exposure are (1) reduction at the source, (2) reduction of transmission, and (3) process modification.

1. Reduction at the Source

The acceleration level usually increases with an increase in the speed at which the tool is operated (e.g., a chain saw operating at two-thirds throttle produces significantly less vibration energy [acceleration] than one operating at full throttle). A tool designed to operate at a reduced speed while providing adequate power for the job could be beneficial. The relationship between the weight of the tool and the power needed to drive the tool will also influence the amount of vibration produced. The reciprocating gasoline engine used to power some tools is a major source of vibration. A rotary gasoline engine or an electric motor as a power source may be a successful alternative, provided it meets the operational requirements. If several tools are available that serve the same function, the tool producing the lowest acceleration should be chosen.

How well the tool is maintained will influence the level of vibration during operation. A sharp chisel or saw chain, a flat-dressed grinding wheel, and a finely tuned engine will reduce the vibration level. To maintain the optimal level of tool maintenance, the operating personnel must be adequately trained in maintenance procedures and be aware of the need for maintenance. A scheduled maintenance program should be established.

2. Reduction of Transmission

The vibration energy produced by the vibrating tool must be transmitted to the operator's hands or arms to produce a harmful effect. Any strategy that reduces the transmission from tool to hand will help prevent HAVS. Several types of energy-damping materials have been used to cover the handles of the tools or have been incorporated into the fingers and palms of hand gear with varying degrees of success. Some materials will reduce vibration transmissions at low-frequencies, and others may reduce those at higher frequencies. Damping materials in handwear are usually more effective for the higher frequencies. However, coverings on the tool handles or glove fingers and palms may interfere with the ability to control the tool during operation and thus may lead to reduced production or increased risk of accidents.

Rens et al. [1987] reported that cotton or leather gloves used for protection against trauma, chemicals, and temperature provide little or no protection against vibration and may even increase the transmission of the vibration.

Another approach to reducing vibration transmission is the use of offset handles, spring-loaded handles, and shock-adsorbing exhaust mechanisms. Again, the operating efficiency at the tool/work-surface interface would have to be considered. A decrease in the vibration transmission level must not be offset by an increase in the time needed to complete the task.

3. Process Modification

An ergonomic analysis of the entire industrial process is recommended to determine whether changes in some aspects of the process could reduce or eliminate the need for vibrating tools. For example, introducing a different casting process in a foundry might result in smoother castings and might therefore reduce or eliminate the need for grinders or power chisels. Using mechanical aids such as chucks and clamps to hold the piece being worked on can reduce the time and the intensity of the vibration exposure. Introducing automation and robots (e.g., robots used for spot welding to replace hand-held riveting guns) could reduce the need for workers to use vibrating tools. Where the size of the trees and the terrain are suitable, automated logging machines can reduce the need for chain saws to fell and debranch trees. Substituting alternative materials (e.g., plastics for cast metal) might reduce or eliminate the need for grinding or chipping operations.

Where the process produces such extreme vibration forces that they cannot be adequately controlled by any means, complete abandonment of the process may be the only feasible solution. Although such a situation may never occur, the possibility must be kept in mind.

C. WORK PRACTICES

Because the pathophysiologic effects of using vibrating tools are related to vibration intensity and use time, the total daily, weekly, and yearly exposure time and the daily exposure schedule are important factors in preventing workers from developing HAVS. The epidemiologic data and clinical experiences discussed in Chapter IV suggest some practical and acceptable work practices that can be implemented to reduce the health impact of using vibrating tools.

Saito [1987] studied the effects of limited tool use time on the presence of HAVS in 155 chain saw operators between 1978 and 1983. Each year the operators were medically examined. Skin temperature, vibratory threshold, recovery of nail bed color after compression, and pain sense were measured before a 10-min exposure of the hand to cold water (10°C) and 5 and 10 min after exposure. The results of 6 years of observation suggest that limiting chain saw use time can help prevent the occurrence of HAVS. The suggested chain saw use schedule was as follows:

One operating cycle (min)	10
Total operating time per day (hr)	2
Consecutive days of use	2
Operating hours per year	320
Upper age limit (years)	55

The daily duration of exposure can be regulated by the length of the workday or by introducing exposure/nonexposure cycles of varying lengths throughout the usual workday. Most exposures are not continuous throughout the workday but consist of actual tool operation of varying lengths of time interposed with scheduled and nonscheduled periods when the tool is not in operation. The large number of possible combinations of work/rest cycle schedules permit choosing one that will best fit the requirements of most industries.

Types of exposure schedules that are applicable include the following:

- Alternating work tasks involving a vibrating tool with some other task that does not involve exposure to vibration (on hourly or daily basis)
- Limiting daily use of vibrating tools as much as possible if acceleration is high
- Limiting use of vibrating tools to 1 or 2 days a week
- Scheduling sufficiently long rest periods each hour to reduce the time-weighted acceleration levels

D. ERGONOMIC CONSIDERATIONS

The amount of the tool-produced vibration that is transmitted to the hands and arms of the operator is influenced by (1) the grip force with which the tool is held, and (2) the force applied by the operator holding the tool against the workpiece [Sakurai and Matoba 1986, Farkkila 1978]. The tool should be held as loosely as safe tool control and operating requirements permit. The force applied to hold the tool against the workpiece should be minimal. The weight of the tool should be used to help provide the required tool/workpiece interface pressure for optimal working speed and efficiency. Moisture at the hand/tool interface (sweat or liquids) may require the worker to exert greater grip force to control the tool. A slip-resistant interface surface is desirable.

Another important ergonomic factor is the position of the body while operating the tool. The angle of the wrists, elbows, and shoulders during tool operation will influence the level of stress exerted on the joints and tendons and the incidence of such problems as tendinitis, carpal tunnel syndrome, tennis elbow, painful shoulders, and HAVS.

An ergonomic analysis of how the work is done is important. Such an analysis can determine the operating practices that may require modification to minimize health problems.

E. PROTECTIVE CLOTHING AND EQUIPMENT

Two generic types of protective clothing and equipment may be used to provide protection against the effects of vibration. These include (1) those that reduce transmission of vibration energy to the hand and (2) those that protect against exposure to cold and trauma.

Various types of vibration-damping materials have been incorporated into gloves and mittens to protect the user of vibrating tools. If these are sufficiently successful as energy dampers, this approach could be very acceptable. For most tasks involving vibrating tools, hand gear of some type is used for protection against trauma and cold. Presently, the major problem is finding energy-damping materials that (1) provide adequate damping with minimal thickness so that the dexterity required for safe and efficient tool operation will not be reduced, and (2) have adequate damping characteristics over the vibration frequency spectrum associated with HAVS. Although several materials are available, an optimal, all-purpose material is not available.

Acute episodes of white finger, especially in the early stages of HAVS, are frequently triggered by exposure of the hands or body to cold. Thermal protection by adequate body clothing and handgear to prevent hand or central body cooling might reduce the frequency of the attacks. However, protecting the hands and body in cold weather is a complex problem that depends on many interacting factors such as

- Air temperature
- Wind speed

- Presence of rain or snow
- Sunshine or other radiant heat source
- Water permeability of clothing and handwear
- Vapor permeability of clothing and handwear
- Air permeability of clothing and handwear
- Insulation value of clothing and handwear
- Metabolic heat production
- Exposure time
- Fit of clothing
- Dryness of the handgear
- Compression of insulation (hand grip force)

The insulation value of clothing is expressed in clo units (1 clo = 5.55 kcal/m^2 per hr per °C). A clothing ensemble that will keep a sedentary individual in thermal balance at a calm air temperature of 23.9°C (75°F) has about 1 clo of insulation value. Clothing that is 1/4-in. thick provides about 1 clo of insulation. The insulation value of clothing under minimal airflow conditions is not a function of fiber or fabric type but depends on the amount of air trapped between the fabric layers or between the fibers.

If the clothing is not adequate to prevent a negative body heat balance, the circulatory system will respond with a peripheral vasoconstriction, particularly of the fingers and toes. Thus exposure to cold air may precipitate an attack of white finger, especially in susceptible individuals with HAVS. For a discussion of cold weather clothing, see Horvath [1985], Goldman [1973], Belding [1973], Newburgh [1949], ACGIH [1988], and NIOSH [1986].

Besides the insulation value of the clothing and handwear, the following other factors should be considered for cold weather operations:

- In the presence of rain or snow, a water-repellent outer clothing layer should be used.
- Handgear should be kept dry. If the handgear becomes wet, a change to dry gear should be made and the wet articles should be dried before being used again.

- In cold conditions (<0°C or 32°F) when wind velocities are greater than 0.5 mile/hr (0.8 km/hr), air-impermeable coverings for hands and torso should be provided. Wind barriers to reduce airflow over the body surface can effectively change the rate of heat loss.

- Warm-up breaks may be required even when the air temperature is above freezing. A work/warm-up schedule for a 4-hr shift is presented in the TLV on cold stress proposed by the ACGIH [1988]. Because the blood circulation of the fingers is especially sensitive to even short exposures to cold, responding by acute vasoconstriction and reduced blood flow, constant vigilance must be exercised to protect the fingers from cold exposure when using vibrating tools. Exposing the hands to cold can cause a vasoconstriction even though the body as a whole is in thermal balance and the torso skin temperature is normal. Warm-up facilities may range from portable handwarmers to whole-body warming shelters.

- Battery-powered, electrically heated handgear is, in some situations, a viable solution to cold-induced vasoconstriction of the fingers.

F. WORKER TRAINING

Because of the wide range in tolerance to vibration within a group of workers, it is imperative that each worker be instructed in the recognition of early symptoms of HAVS and in the cause and prevention of HAVS. A worker training program is vital to prevention and control of HAVS and should emphasize the following, at a minimum:

- Recognition of the early signs and symptoms of HAVS, including finger tingling, numbness, and episodes of finger blanching

- Reporting of all signs and symptoms

- Role of medical supervision in prevention and control of HAVS

- Possible health effects of continued operation of vibrating tools

- Reversibility of early signs and symptoms

- Role of tool maintenance and vibration production

- Ergonomic aspects of tool use, including the influence of handgrip force, pressure exerted at the tool/workpiece interface, manner in which the tool is held, body posture, etc.

- Need and procedures for keeping the body and hands warm and dry

- Use of protective clothing and equipment
- Work/rest schedules to control exposure duration
- Informing supervisor about any abnormal functioning of the tools
- Possible aggravation of HAVS from smoking and use of some drugs

The training should be provided to each new worker and repeated at intervals for each worker using vibrating tools to ensure continued worker awareness of the potential problems. Because the earliest signs and symptoms of HAVS are periodic numbness or tingling of the fingers, or episodic blanching of the fingertips, the worker will be the first to recognize that something unusual is occurring. A trained worker can recognize the disorder at the early stages, when further progression can be prevented or reversed.

G. MEDICAL MONITORING

Medical monitoring of workers using vibrating tools should be a primary approach to HAVS prevention and control, but it presents some difficulties because there is no specific clinical or medical test to objectively diagnose or assess the presence of HAVS. HAVS, as the name suggests, is a composite of signs and symptoms. The medical monitoring program should consist of (1) a preplacement medical examination with special attention to peripheral vascular and neural factors, (2) yearly or more frequent examinations designed to elicit responses that may be related to early HAVS, and (3) continued communication with the workers to ensure that early signs and symptoms are reported. Regardless of the signs and symptoms present, a diagnosis of HAVS is not justified without an occupational history of the use of vibrating tools.

1. Preplacement Baseline Medical Examinations

The primary purpose of the preplacement medical examination is to identify (1) any worker who has HAVS from previous vibration exposures, (2) workers who have primary Raynaud's disease, (3) workers who have other disorders with signs and symptoms similar to HAVS (e.g., peripheral vascular or neural disease), (4) workers who are on medications or drugs that may have peripheral vascular or neural effects and (5) baseline data for comparison with subsequent examinations. The preplacement medical examination should be structured to elicit information pertinent to these points.

Specific screening tests considered useful in the diagnosis of HAVS are listed in Chapter IV, D (Screening and Diagnostic Tests). At a minimum, the preplacement medical examination should include tests or questions to identify the following:

- Peripheral neural status--light touch, pain, temperature, two-point discrimination, depth perception, vibrotactile sensitivity level

- Peripheral vascular status--finger blood flow response to the cold and cold provocation test with before, during, and after plethysmography conducted under standardized conditions
- Presence of carpal tunnel syndrome, tennis elbow, or other work-related cumulative trauma disorders of the hand or arm
- Old injuries that could have peripheral vascular or neural effects (cold injury, burns, trauma, etc.)
- Primary Raynaud's disease, and its history
- Other disorders that may have similar peripheral vascular or neural signs and symptoms (polyneuritis, occlusive vascular disease, thromboangiitis, chemical intoxication)
- Use of therapeutic and/or other drugs that have peripheral vascular or neural effects (including alcohol and tobacco)
- Anatomical abnormalities that may interfere with the safe use of the vibrating tools
- Presence of cold sensitivity and previous cold injuries
- History of past use of vibrating tools (including type of tool and duration of use)
- Age, sex, race, body weight, and other demographic data that may be relevant to differences in peripheral neural and vascular function and cold sensitivity
- Baseline measurements of vibrotactile threshold, grip force, muscle strength, etc.

2. Periodic Medical Examinations

Periodic medical examinations for workers exposed to vibration from vibrating tools should be offered on a yearly basis or more frequently for affected workers on the recommendation of the responsible physician. The periodic medical examination should emphasize tests and questions that will elicit information on the early signs and symptoms of HAVS or the progress of its severity.

The periodic medical examination should include

- Review of worker health complaints
- Review and updating of the data derived from the preplacement examination

- Repetition of tests and procedures directed to peripheral vascular and neural functions and symptoms

- Assessment of peripheral vascular and neurological signs and symptoms, aesthesiometric and vibrotactile test results, grip strength, and presence of musculoskeletal symptomatology to establish whether HAVS has developed to Stage 1 or has progressed further

3. Medical Surveillance

To ensure that the control practices provide adequate protection to workers exposed to hand-transmitted vibration, the responsible health professional can use the workplace exposure data, periodic medical data, and the interview history to determine any significant changes within a worker or group of workers since the previous examination. These events may include complaints of episodic numbness, tingling, or cold-induced white fingers; changes in grip strength and muscle force; and pain in the hands, arms, and shoulders. The events may lead the physician to suspect overexposure of the work population or a change in an individual's health status or susceptibility. The occurrence of these sentinel health events (SHEs) could signal a breakdown of or inadequacy of the vibration exposure control systems established at the workplace.

H. RECORDS AND RECORDKEEPING

Records of the data obtained from the following measurements are required to establish adequate control procedures: (1) updated acceleration and frequency characteristics of the vibrating tools used, (2) hours per day the worker operates the tool, (3) intraday exposure pattern, (4) years of operating the tool, (5) nonoccupational exposure to hand-arm vibration, (6) exposure year in which HAVS symptoms first appeared, (7) stage assessment of HAVS, (8) environmental conditions at the workplace, including air temperature, wind speed, and humidity, (9) type of personal protective clothing and equipment used, (10) results of preplacement and periodic medical examinations, (11) change in medical status between medical examinations, and (12) worker training programs.

The records on vibration exposure levels and times and medical status should be retained in accordance with the requirements of 29 CFR 1910.20(d). HAVS should be considered a reportable occupation-related disorder.