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CONTROL OF SNOWMOBILE NOISE
VOLUME I
TECHNOLOGY AND COST INFORMATION

JUNE 1974

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Office of Noise Abatement and Control

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1. INTRODUCTION

The snowmobile is one of the most popular recreational vehicles in the northern United States and Canada. From a production of 10,000 units in 1963 the industry has grown to almost 600,000 units in 1973. There are an estimated 2.3 million snowmobiles in use today and of these, one million are less than 3 years old. Pure recreation accounts for 98 percent of snowmobile use and the average snowmobiler spends 14 hours per week[1] during the winter season on a machine he purchased for an average price of $1146.

In 1971 there were 69 known snowmobile manufacturing firms in the world. At present, 38 firms are known to make snowmobiles and the eight largest firms control over 70 percent of the entire market. Last year the industry's estimated sales volume was $500 million.

Due partly to its rapid growth in popularity and partly to the fact that earlier models were very noisy (levels in excess of 100 dBA at 50 feet were not uncommon during the 1960's), many complaints of annoyance have been registered against snowmobiles. In addition to the annoyance factor, there are indications that snowmobile noise might cause permanent hearing damage to operators and passengers. Finally, conservationists are concerned that snowmobile noise might be detrimental to wildlife at a time when they are particularly weak and vulnerable. Many studies have been conducted on these aspects of snowmobile noise with the result that legislation has been introduced in many states to restrict noise levels. Manufacturers have responded to this legislation somewhat by producing quieter snowmobiles for use today, and by instigating research and development programs to achieve further reductions in noise levels of future models. This report documents the costs that are expected to be incurred by manufacturers to produce snowmobiles quieter than presently available models.

2. STUDY APPROACH

A feasibility study on the noise reduction of one or two snowmobile models would result in information of limited general application because of the wide variety of snowmobiles on the market today. Such studies have been carried out in the past by independent research organizations and their results have been well documented although not always well received by the industry. Prodded by recent legislation, most manufacturers have begun research on their own. As this study progressed, a great deal of data were made available by manufacturers, government agencies, trade magazines and independent research groups. The scope and quality of the data was considered sufficient to justify abandoning any in-house tests of noise reduction for this program.

A total of 38 manufacturers of snowmobiles were contacted by telephone and by letter during the initial phase of this project. Manufacturers were asked to respond to the following questions:

- Noise level data measured per the SAE J192 test procedure for all models for the years 1972, 1973, and 1974.
- Cost of noise reduction techniques and materials used for 1973 and 1974 model year snowmobiles
- Cost of noise reduction techniques and materials planned for use on 1975 and 1976 model snowmobiles
- Performance changes encountered or anticipated due to noise reduction
- Weight increases encountered or anticipated due to noise reduction
- Opinions on reasonable future noise levels and test procedures
- Available operator noise levels and procedures used to measure them
- Use cycle or typical operation data

- Subsource component contributions to overall noise level
- Numbers of units produced in each model designation

Market penetration data provided by manufacturers and an independent source,[2] together with estimates of the production of some of the smaller manufacturing firms, indicate that the manufacturers who were asked to supply data represent approximately 97 percent of the snowmobile market. A list of all manufacturers that were contacted is included in Appendix A to this report.

After the initial contacts were made, several representative firms were visited. During these visits, in-depth discussions were held concerning snowmobile noise technology, feasibility of noise reduction techniques, and cost of such reduction. In addition to the questions listed above, discussions were held on snowmobile life expectancy, the ability of smaller firms to stay in business, and specific engineering techniques used for noise reduction. In all, personal discussions were held with engineering representatives of seven major snowmobile firms, accounting for over 55 percent of all units manufactured. These discussions were held at the manufacturers' facilities, at Wyle Research, and at the International Snowmobile Industry Association 1973 Trade Show in Toronto.

In general, snowmobile manufacturers were very cooperative in supplying information for this project. Fourteen of the 38 manufacturers responded to our request for data. These 14 manufacturers represent a combined market penetration of over 80 percent of the snowmobile market. Many of the manufacturers who make up the remaining 20 percent of the market indicated an interest in supplying information but apparently found it difficult to do so within the time limits imposed by the study contract.

Some of the data provided by manufacturers was considered to be of a proprietary nature. In these cases, it was not included in this report in specific detail. In many cases, proprietary data was generalized to facilitate its use without violating its confidential nature.

3. THE SNOWMOBILE INDUSTRY

Snowmobiles are a relatively recent, consumer oriented, leisure time product. Only limited financial and engineering resources are required to enter the business at this stage since the designs are still simple and consumer preferences not yet that well established. For this reason, the industry supplying the product is still in transition, with new firms entering the industry and older firms exiting after encountering production, marketing or financial problems.

A profile of the industry presents, therefore, an unusual range of participation. At one extreme are very large manufacturing firms with diverse business interests attempting to capitalize on their production and marketing skills and viewing snowmobiles as a diversification move from their other endeavors. At the other extreme are small organizations with limited overall capabilities, yet successful in assembling a competitive vehicle.

It is premature to anticipate the characteristics of a firm which will successfully compete in this industry in the long run. Even present market penetration cannot be viewed as an indicator of future market dominance. It appears clear, however, that an engineering capability competent of meeting regulatory standards is a prerequisite for a long term survival.

Industry Grouping

In order to test the sensitivity of survey results to the type of firm in the industry, supplying firms were evaluated in terms of their corporate affiliation, product lines and corporate size. Two distinct categories emerged from this analysis, each possessing a set of internally consistent characteristics.

The first category (Group 1) encompasses very large firms with annual sales in excess of $1 billion and medium size firms with annual sales ranging from $100 to $500 million. For the large firms, snowmobiles are most probably viewed as a potential diversification move into the booming leisure-time market. The medium size firms generally have a heavy consumer orientation geared particularly to leisure-time products. Typically these firms also manufacture and market lawn mowers, tennis and golf equipment, camping supplies and associated products. An overriding characteristic of all the firms in this group is that they possess sizable engineering and financial resources.

The second category (Group 2) consists of smaller firms, for which snowmobiles are the primary business activity. Their skills range from assembly operations to limited engineering and design. They face considerable marketing problems and their financial resources are limited. Since they do not face the involved decision and approval processes prevalent in the other category, their strength is in their ability to respond to consumer and regulatory demands if changes can be accomplished with the resources they have in hand. Their annual sales are typically in the $10 to $30 million range. The two groups of manufacturers are listed in Table 1 according to this grouping based on the information available at the time this study was made.

Table 1

Grouping of Snowmobile Firms

Group 1 (Large Manufacturers)	Group 2 (Small Manufacturers)	
AMF (Harley-Davidson)	Alouette	Leisure Vehicles
Arctic	Alsport	Lori Engineering
Bombardier	Auto Ski	Melvin Manufacturing
Coleman	Autotechnic	Moto-Kometic
John Deere	Boa-Ski	Northway
Massey-Ferguson	Brutanza	OEM
Mercury	Chaparral	Ontario Drive and Gear
OMC	Columbia - MTD	Raybon
Polaris	Fun Seasons	Roll-O-Flex
Suzuki	Gilson	Rupp
Yamaha	Griswold Swinger	Speedway
Sno-Jet	Herter's	U.S. Sports
Scorpion	Jac Trac	

4. SNOWMOBILE CONSTRUCTION AND NOISE CHARACTERISTICS

Introduction

Snowmobiles are basically recreational vehicles designed for versatility, maneuverability and ability to go anywhere over snow. A typical snowmobile, as shown in Figure 1, is usually powered by a two-cycle gasoline engine with either a single or double piston configuration, although the rotary Wankel engine has been introduced in some models by several manufacturers. The power from the engine is transferred through a variable speed drive system (centrifugal clutch) to the driving track. The track is a continuous loop of rubber or polyurethane that may be reinforced with steel cleats for improved traction. It is normally supported on a series of spring-mounted wheels called bogies, although in the past few years, bogie suspension systems have been replaced with sliding rail systems or a combination of sliding rails and bogies. Steering is accomplished by means of skis that extend through the bottom of the front of the chassis supporting the weight of the front end. The skis are maneuvered by a handlebar arrangement similar to that found on motorcycles. The engine is usually mounted on the front of the chassis and covered with a cowling to form the engine compartment. The driver sits on a padded seat covering the rear of the chassis.

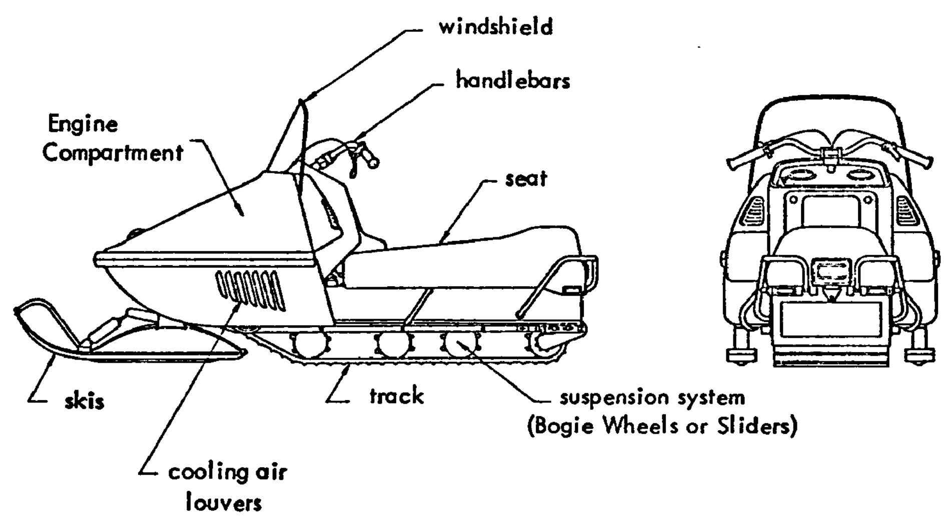


Figure 1. Typical Snowmobile Configuration

Because snowmobiles are designed to go anywhere, they must be light enough to float over powdered snow. Heavy machines may be hazardous to ride in an area where snow conditions change from hard-packed snow to loose powder. For this reason, extensive use is made of aluminum and fiberglass by the manufacturer. Most popular-sized snowmobiles weigh between 300 and 450 pounds with an average dry weight (no fuel) of 398 pounds. Typical fuel capacity is 4 to 6 gallons. A weight design goal used by one manufacturer to prevent sinking in loose snow is 0.5 pounds per square inch of track surface.[3] For large snowmobiles, this corresponds to about 425 pounds maximum weight.

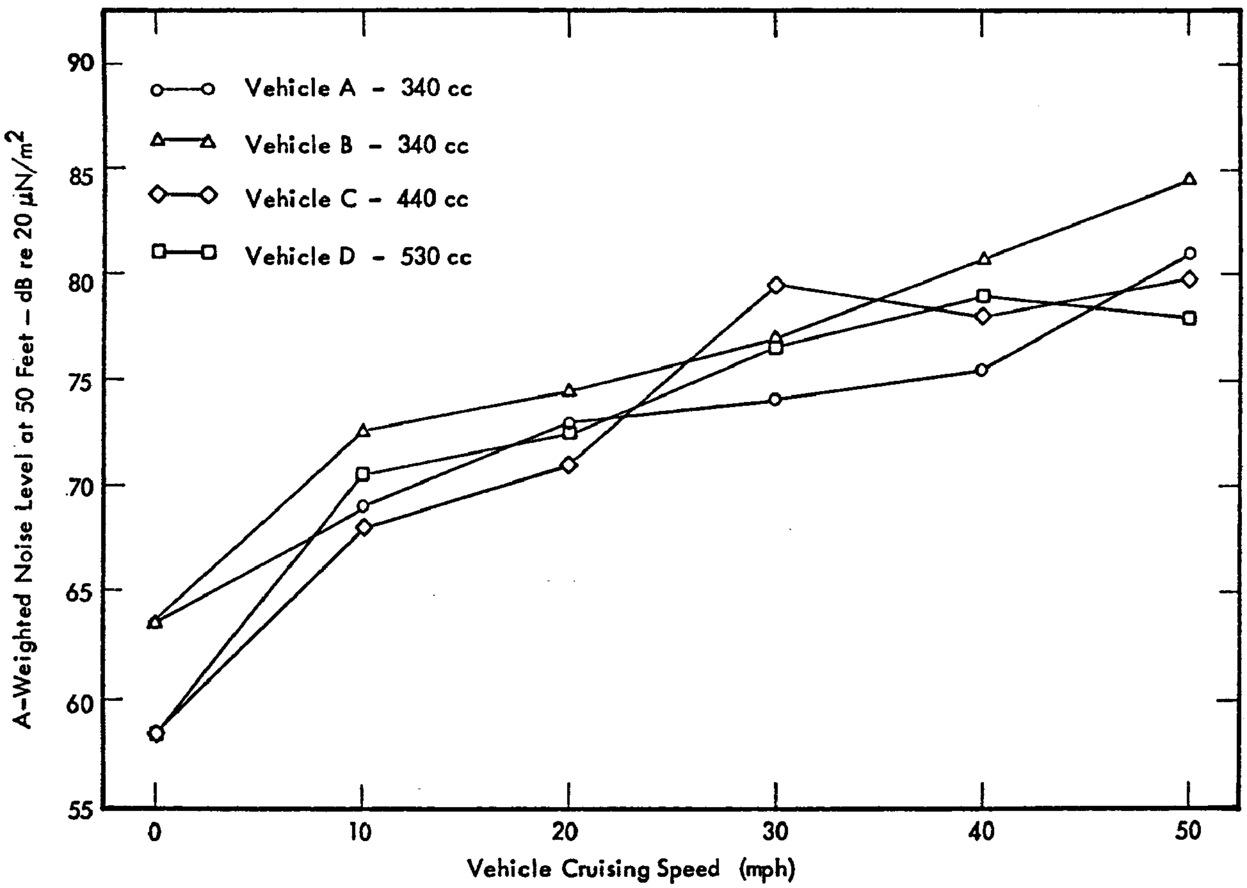
Typical top operating speed of large stock snowmobiles is about 50 miles per hour although many racing machines are capable of much higher speeds. Normal trail speeds are 20 to 30 miles per hour.[4]

Measurement Procedures

Snowmobile noise levels are most commonly measured in accordance with the Society of Automotive Engineers (SAE) Recommended Practice J192 (See Appendix C). Under this procedure, the snowmobile is accelerated under wide open throttle until maximum engine speed is attained. The recording microphone is placed 50 feet from the centerline of the vehicle path opposite a point 25 feet beyond the initial point of maximum speed. Details of this measurement procedure are included in Appendix C. All data in this report have been taken using the SAE J192 procedure unless otherwise specified. Provision is made in the procedure for a 2 dB tolerance to allow for variations in test site and atmospheric conditions and differences in nominally identical vehicles.

A standard procedure for measuring noise produced by a vehicle should provide a method of obtaining accurate and repeatable noise level values. In addition, the measured noise levels should correlate well with the noise produced by the vehicle under normal operating conditions.

One aspect of J192 that should be noted is that all noise levels measured using this procedure are at maximum engine speed. The relation between noise level and vehicle speed which is related to engine speed under cruise conditions is shown in Figure 2 for four 1973 production model snowmobiles ranging in size from 340 cc to 530 cc.[4] All four snowmobiles represented in Figure 2 display approximately the same dependence of noise level on vehicle speed. At typical trail speeds of 20 to 30 mph, noise levels at 50 feet range from 71 dBA to 79 dBA whereas at the maximum speed of 50 mph the levels range from 78 dBA to 84 dBA. This variation of noise level with velocity indicates that the levels measured according to the standard SAE test procedure are not a true indication of snowmobile noise levels since maximum velocity, and thus maximum engine speed, is not a typical operating condition.

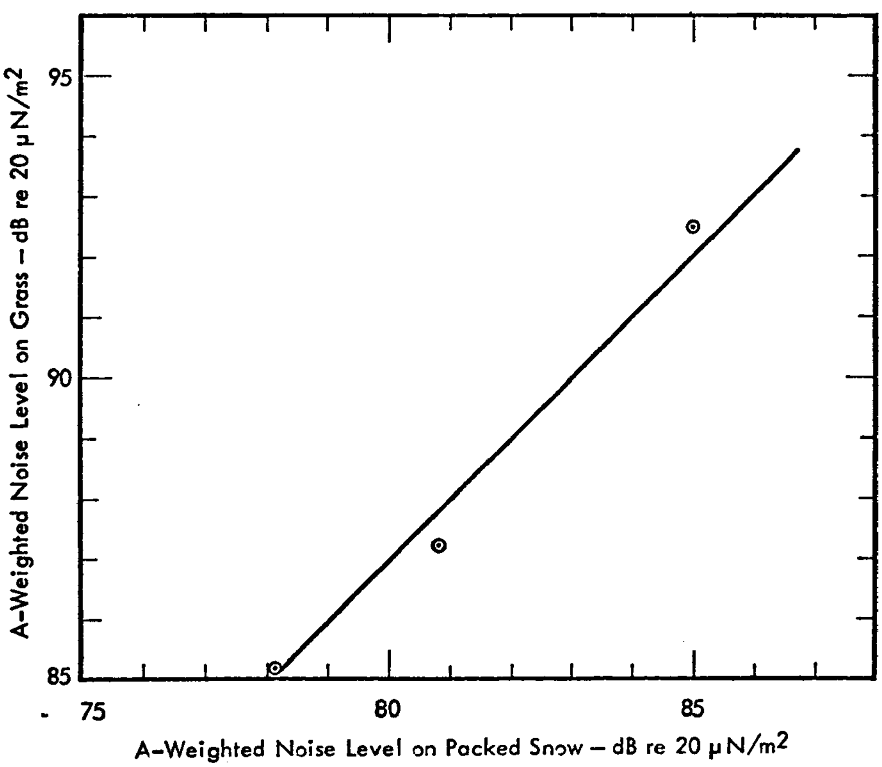


Source: George Gowing (See Reference 4).

Figure 2. Snowmobile Pass-By Noise Versus Speed
1973 Model Vehicles

Another debatable feature of J192 is the specified test site surface. Since snow conditions can vary considerably and at best are difficult to control, it has been specified that the test be conducted on a grass surface. However, most manufacturing facilities are located in the northern United States and Canada, so ironically all snowmobile testing must be done during warm months before it begins to snow. To alleviate this problem of limited testing days, a new revision to J192 now permits the use of either a grass or snow covered test site. This is, no doubt, a preferable approach from the manufacturers' point of view. All noise level data presented in this report was recorded in 1972 when grass was the only allowable test surface.

The variation in noise levels measured over grass and snow is shown in Figure 3. According to one manufacturer who furnished this information, noise measured over grass exceeds that measured over snow by approximately 7 dB.[5] A second manufacturer carried out a similar comparison and reported that noise measured over grass exceeds that measured over snow by approximately 4 dB.[4]



Source: Yamaha International (See Reference 5).

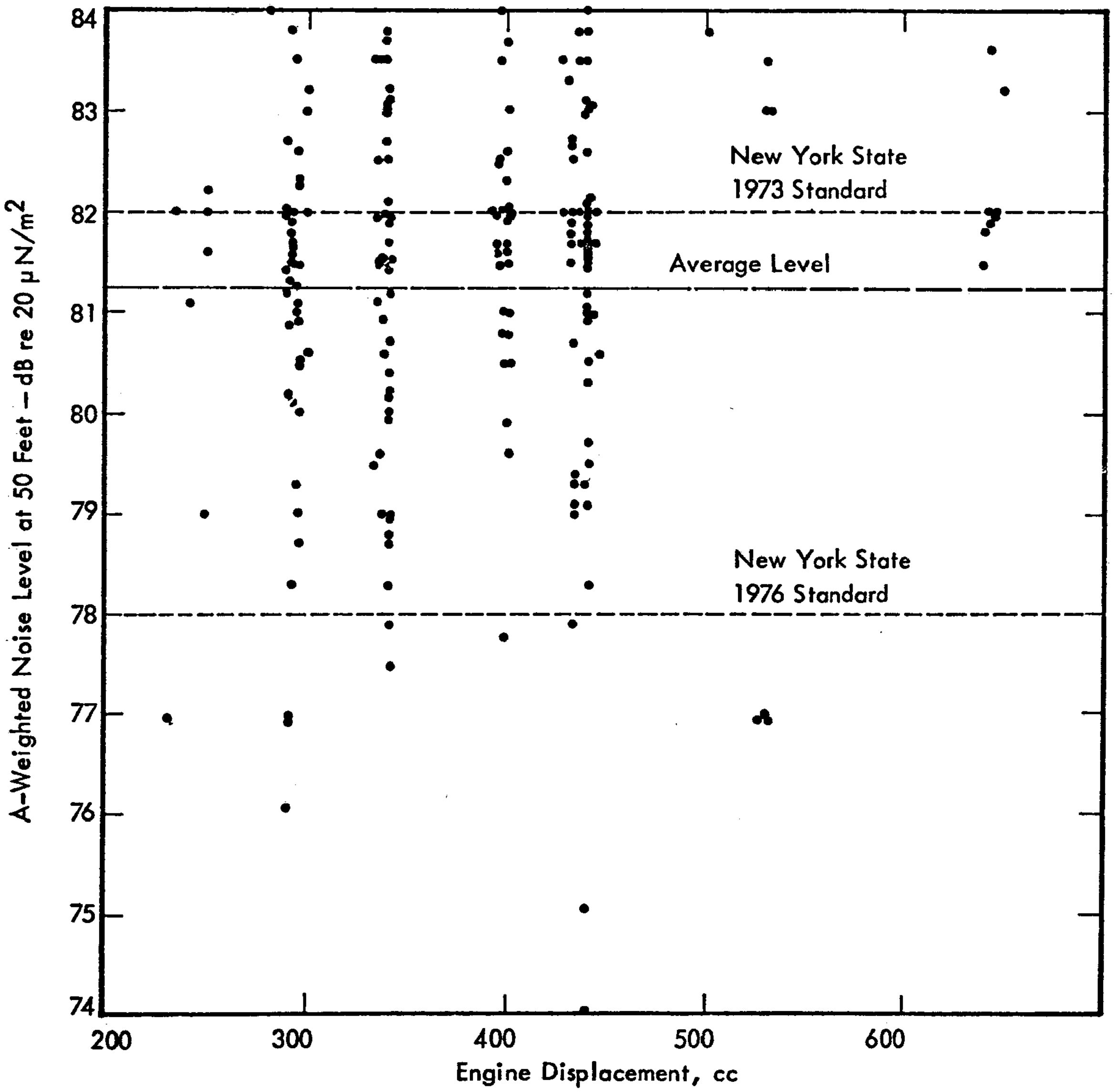
Figure 3. Relation Between Noise Levels Measured on Packed Snow and 3 Inches of Grass

The repeatability of measurements made on snow is still questionable due to the wide variety of snow conditions that may exist. One manufacturer has found that noise measured over softly packed snow may be as much as 5 dBA less than noise measured over hard packed snow.[5] As a possible solution to this problem, several manufacturers have suggested the use of an artificial surface that could be used during the winter.[6] Such a technique would provide measurement repeatability and studies could then be made to develop a correlation factor between measured noise and noise produced under typical operating conditions. Obviously, the test site problem will have to be resolved if the J192 test procedure is to become a reliable regulatory tool.

A-Weighted Noise Levels and Spectra

Noise levels produced by snowmobiles have been declining steadily during the last few years reflecting efforts on the part of the manufacturer to quiet his product in response to legislation brought about by public demands for less noise. In a recent study, the noise levels of a group of 20 snowmobiles ranging from 1967 models to 1972 models were measured.[7] The noise levels at 50 feet varied from 77 dBA to 99 dBA with a mean level of 87 dBA. Legislation passed in several states (see Appendix D) set a maximum level of 82 dBA for snowmobiles sold during 1972 and the average level of 1973 models sold that year dropped below 82 dBA.[8]

Figure 4 shows the distribution of snowmobile noise levels (measured in accordance with SAE J192 test procedure on grass) for more than 200 1973 models produced by 36 different manufacturers. The levels are given as a function of engine size ranging from 230 cc to 650 cc with a mean engine size of 369 cc. The four most popular sizes are 295, 340, 400, and 440 cc. Most of the snowmobiles sold during 1972 were certified between 82 dBA and 78 dBA with a mean value of 81.3 dBA. The levels of 82 dBA and 78 dBA are the present New York State Parks and Recreation Department noise standards for the model years 1973 and 1976 (this same New York Standard will limit snowmobile noise to 73 dBA for the 1979 model year). All noise



Source: Reference 8.

Figure 4. Noise Levels of 1973 Model Snowmobiles as a Function of Engine Size (Data Points Represent) Measurements made per SAE J192 Test Procedure on a Grass Covered Test Site)

(All Manufacturers)

levels in Figure 4 are absolute levels; that is, the 2 dB tolerance allowed by the SAE J192 test procedure has not been included.

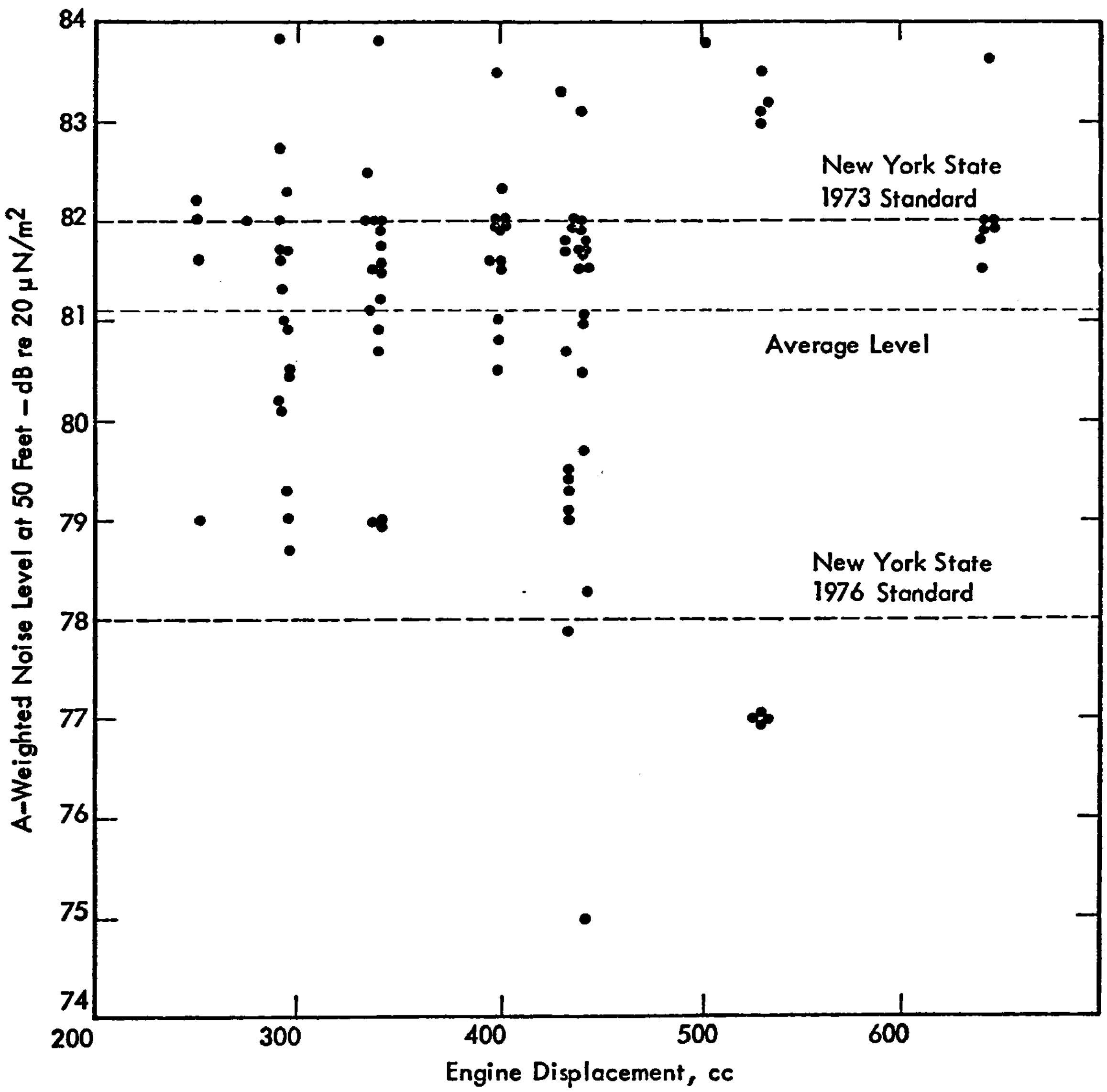
Figures 5 and 6 show the same data presented in Figure 4 broken down by manufacturing group. Group 1 has a slightly lower average noise level than Group 2 but the difference is insignificant. All data points shown on these figures are assumed to be representative of the machines produced by each manufacturer. There is no information readily available indicating the variance associated with each manufacturer's production models.

Figure 7 shows the distribution of noise levels as a function of power-to-weight ratio (in pounds/hp). There appears to be very little correlation. The mean power-to weight ratio is 12.7 pounds/hp. Similar analyses were conducted for maximum rpm, weight and horsepower, but in all cases, noise levels bear little correlation to these engine parameters. The average horsepower of all models is 31.3 hp and the average maximum engine speed is 6350 rpm.

Figure 8 shows the relation between noise level and retail price. Snowmobile prices range from about $600 to $1800, but most of them are priced between $800 and $1400, with a mean retail price of $1146. There is no correlation between snowmobile price and noise level.

Since there is no obvious relation between snowmobile noise levels and other engine parameters, it is not reasonable to categorize current models by any of these quantities. Furthermore, there is no definite separation by utilization for snowmobiles, as they are used almost exclusively for recreation. Hence, they may not be grouped by their intended use. Throughout this report, therefore, snowmobiles will be treated as belonging to one single class.

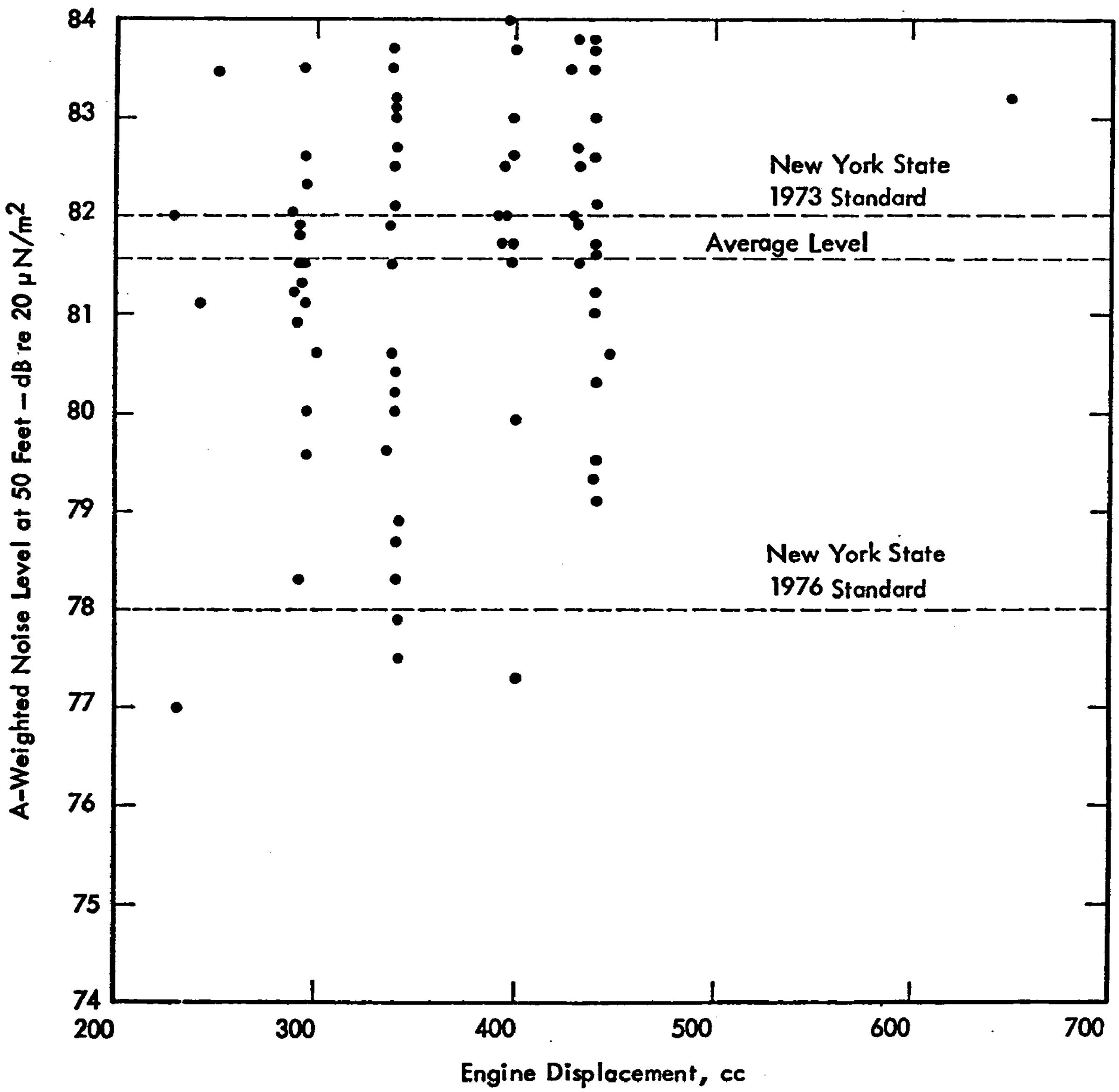
A typical one-third octave band spectrum of snowmobile noise is shown in Figure 9.[5] An interesting feature of the frequency dependence of noise is the ability to identify



Source: Reference 8.

Figure 5. Noise Levels of 1973 Model Snowmobiles as a Function of Engine Size (Data Points Represent Measurements Made per SAE J192 Test Procedure on a Grass Covered Test Site)

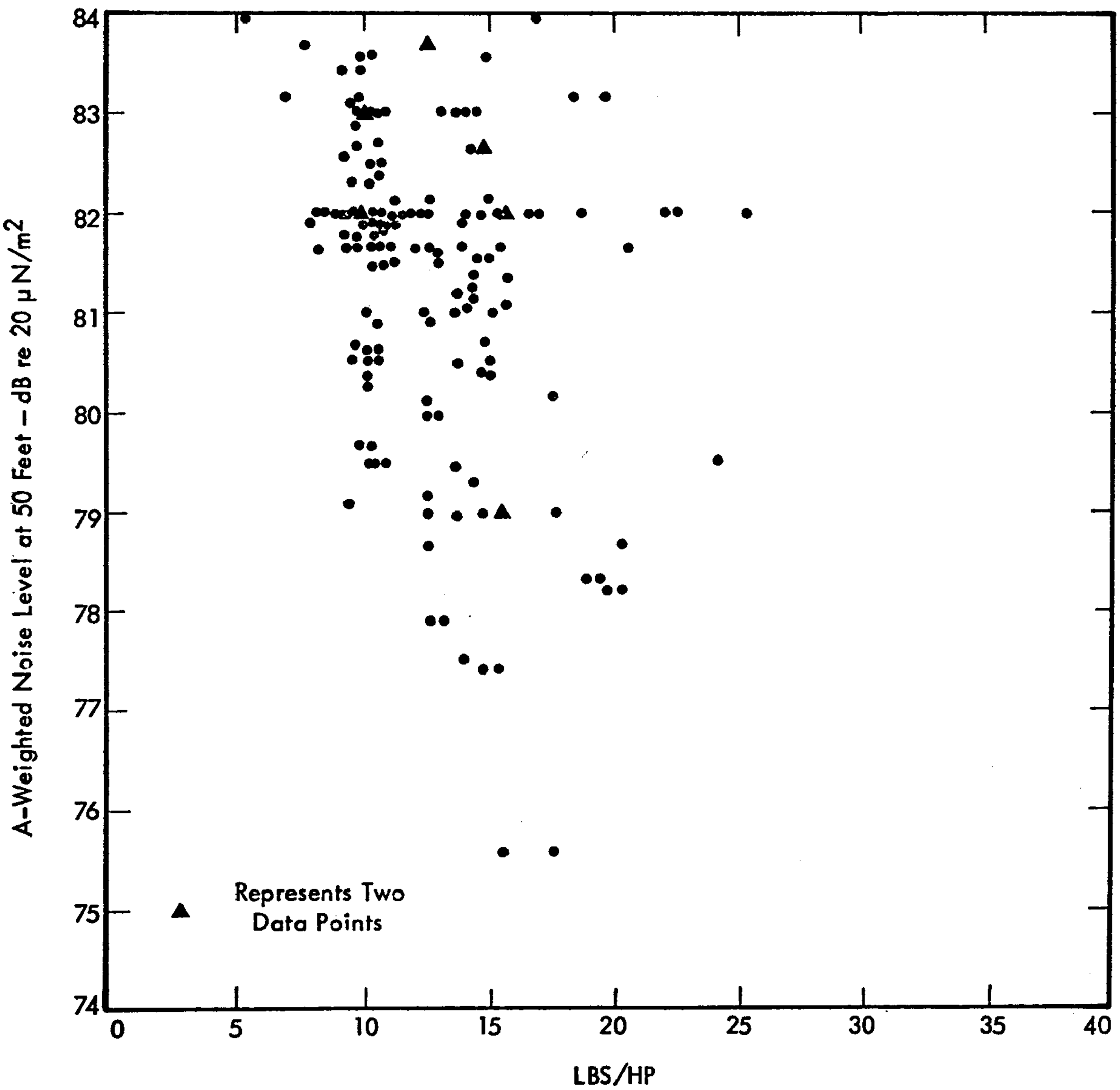
(Group 1 - Large Manufacturers)



Source: Reference 8.

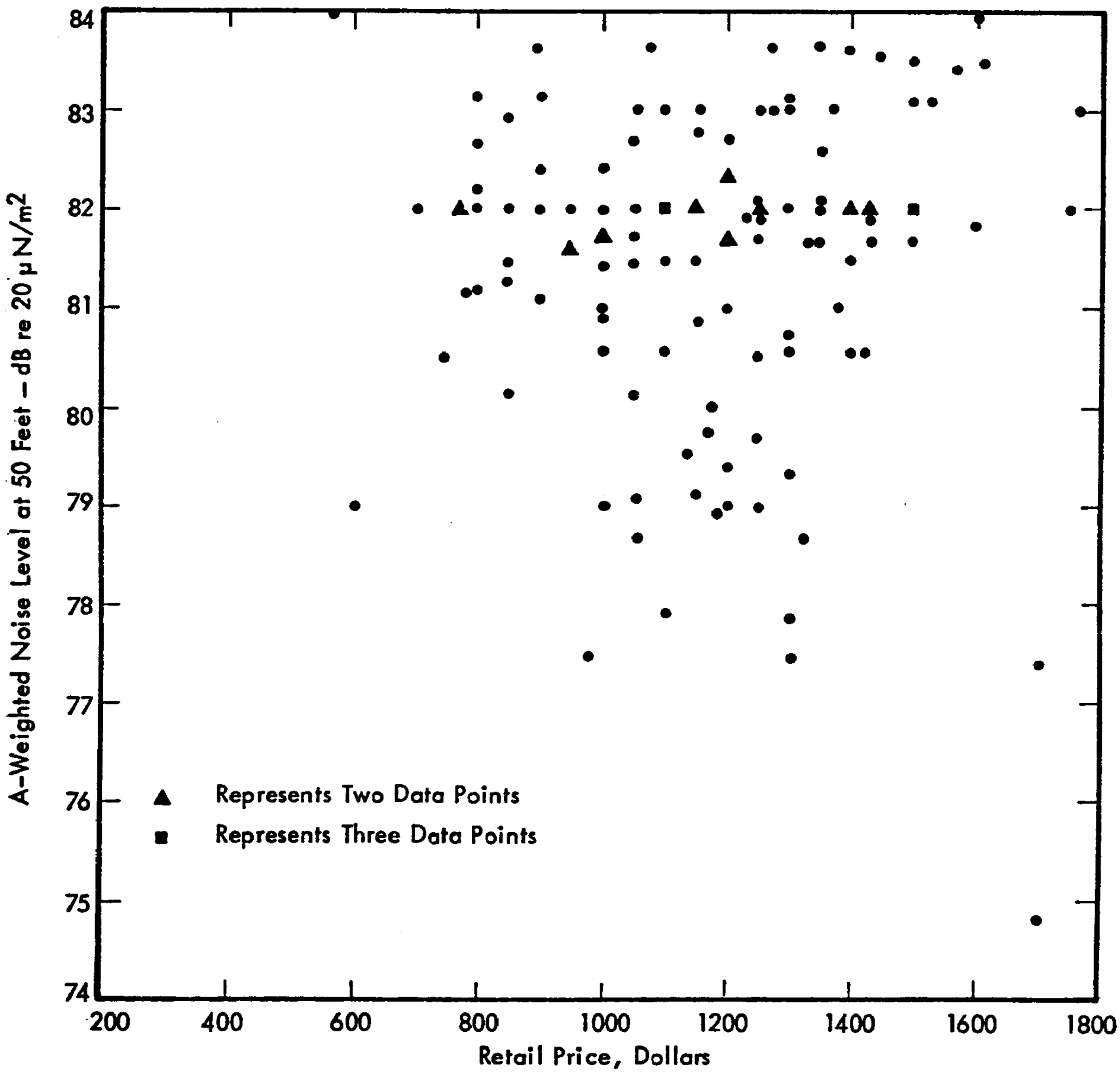
Figure 6. Noise Levels of 1973 Model Snowmobiles as a Function of Engine Size (Data Points Represent Measurements Made per SAE J192 Test Procedure on a Grass Covered Test Site)

(Group 2 – Small Manufacturers)



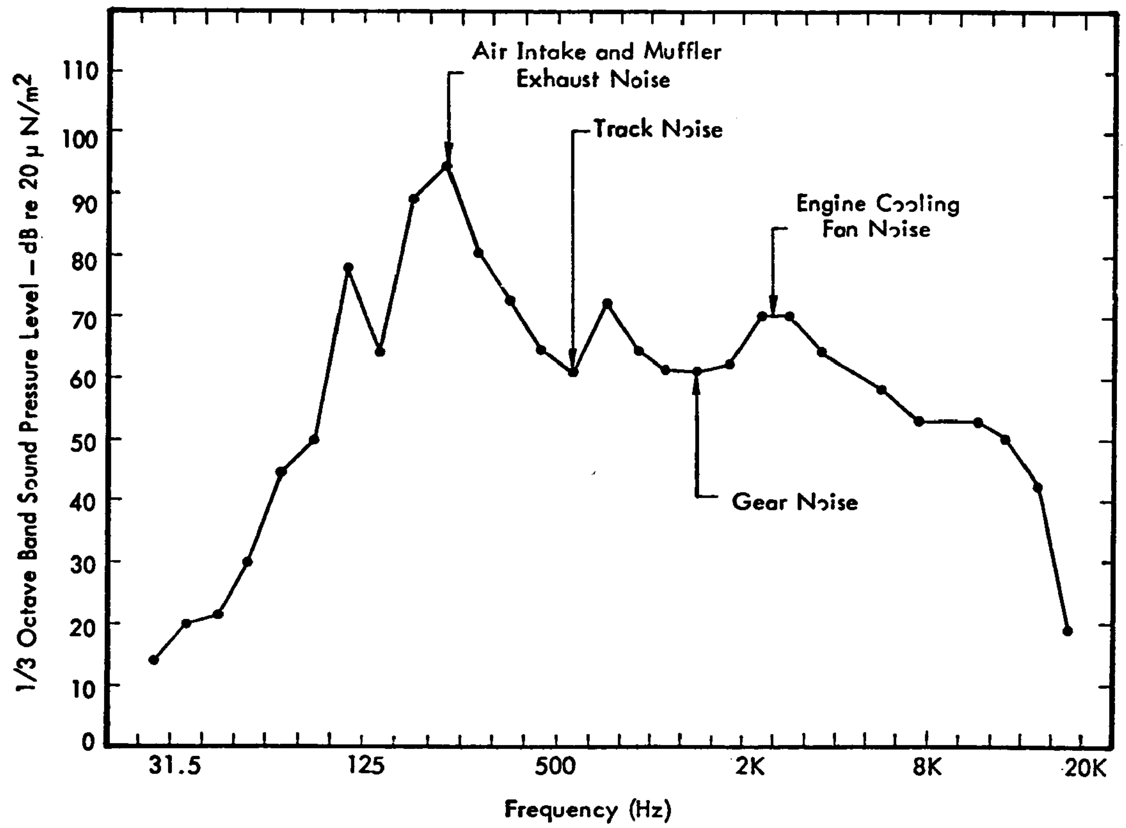
Source: Reference 8.

Figure 7. Noise Levels of 1973 Model Snowmobiles as a Function of Power/Weight Ratio (Data Points Represent Measurements Made per SAE J192 Test Procedure on a Grass Covered Test Site)



Source: Reference 8.

Figure 8. Noise Levels of 1973 Model Snowmobiles as a Function of Retail Price (Data Points Represent Measurements Made per SAE J192 Test Procedure on a Grass Covered Test Site)



Source: Yamaha International (See Reference 5).

Figure 9. Typical Snowmobile Noise Spectrum (per SAE J192)

component noise sources. As seen in Figure 9, the peak near 200 Hz may be associated with intake and exhaust noise; track noise is located in the 500 Hz band and engine gear noise and cooling fan noise are in the 1000 to 2000 Hz region.

Operator Noise Exposure

Due to their proximity to the engine, snowmobile operators and passengers are exposed to noise levels that may result in permanent hearing damage. A recent study found evidence of temporary threshold shift (an indication of permanent hearing damage risk; noise exposures that produce temporary threshold shift in normal ears may ultimately produce permanent hearing loss under conditions of repeated exposure) in

87 percent of the operators tested after as little as 30 minutes of exposure.[7] This indicates that many snowmobile riders are exposed to noise levels that could potentially result in permanent hearing loss over a long period of time. Furthermore, high noise levels at the operator's position prevent him from hearing warning signals such as train whistles and therefore present a definite safety hazard.

In spite of the importance of operator noise exposure, little accurate data is available on actual operator noise levels. A measurement standard is needed that will provide reliable, accurate measurements. Two methods of measuring operator exposure have been proposed; one involves the use of a miniature microphone to monitor the noise at the operator's ear and the other measures noise at the operator's normal ear position without the operator present.[9] Either of these methods should result in reliable measurements without the inaccuracies inherent in sound level meter readings made behind the operator's head.

It would be convenient to be able to relate operator noise exposure to noise levels recorded at 50 feet as this would allow simple field monitoring of operator noise levels with a sound level meter. However, each snowmobile has unique noise radiation characteristics and a simple relation between the two levels has yet to be established.

The data in Table 2 presents operator noise levels and levels measured at 50 feet for 12 different 1973 production model snowmobiles.[4] Noise levels at the operator's ear range from 98 to 114 dBA and noise levels measured at 50 feet range from 78 to 87 dBA. The difference between operator noise level and noise level at 50 feet ranges from 17 to 32 dB. Obviously, the desired relation between the two levels is not available, at least for field measurements made in accordance with the SAE J192 Standard Test Procedure.

Table 2

Maximum Noise Levels at Operator's Ear and at 50 Feet[1]

Vehicle	Level at Operator's Ear,[2] dBA	Level at 50 Feet,[3] dBA	Difference dBA
A	114	83	31
B	98	81	17
C	100	78	22
D	100	78	22
E	114	87	27
F	112	80	32
G	111	82	29
H	109	80	29
I	100	80	20
J	106	85	21
K	108	86	22
L	111	85	26

[1]Source: George Gowing (See Reference 4).

[2]A-Weighted Noise Level in dB re 20 $\mu N/m^2$.

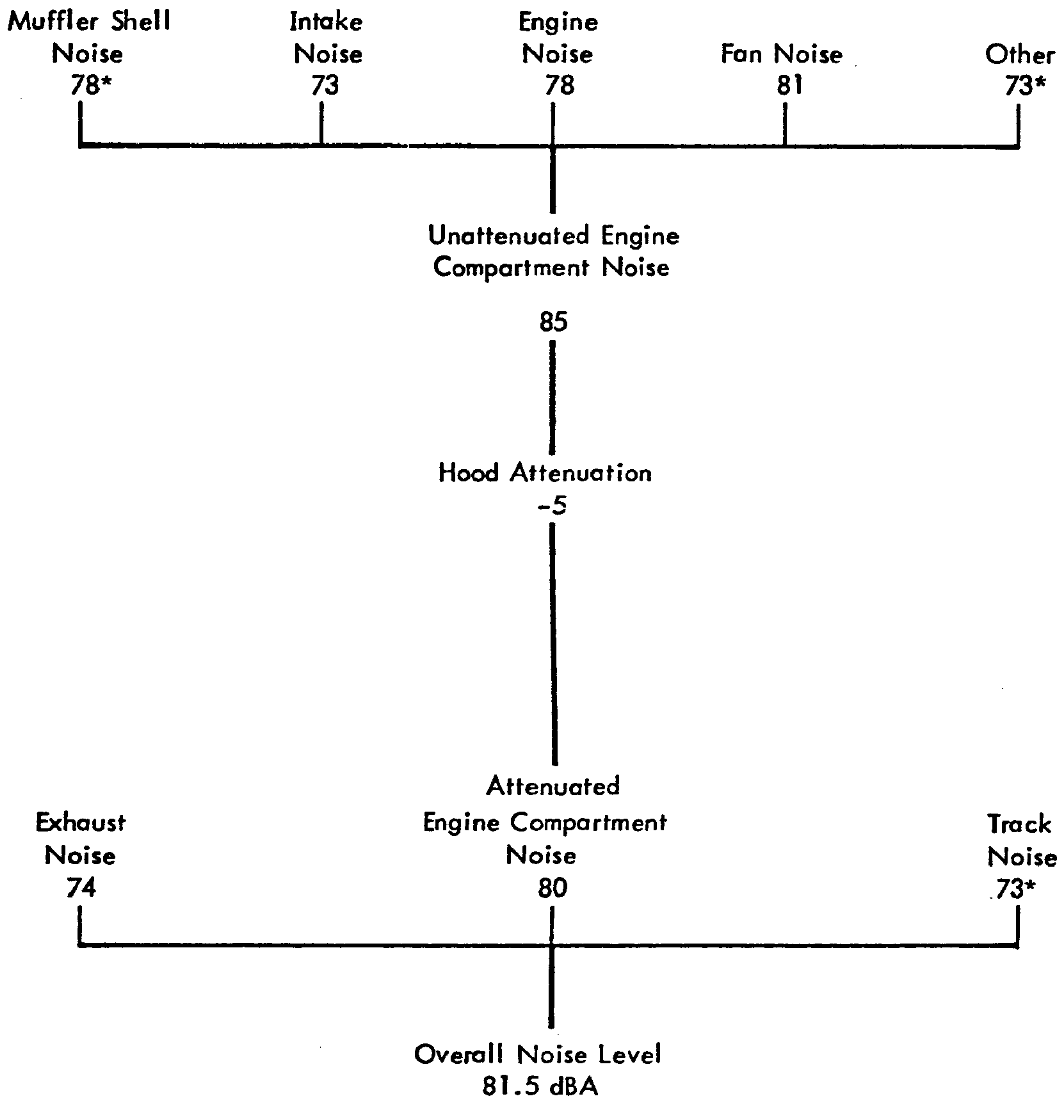
[3]A-Weighted Noise Level in dB re 20 $\mu N/m^2$ Measured per SAE J192 Test Procedure.

Noise Sources

Individual sources of noise may be categorized into three general groups: exhaust noise, engine compartment noise and track noise. This breakdown is shown in Figure 10 for a 1973 Cheetah snowmobile manufactured by Arctic Enterprises[3] although the component noise levels are typical of machines made by other manufacturers.

Exhaust Noise

Exhaust noise is generated by combustion air moving out of the engine in pulses that radiate energy in the 100 to 200 Hz frequency range. For several years, exhaust



Source: G. Englert (See Reference 3).
*Calculated Values. All values are A-weighted noise levels, dBA.

Figure 10. Synthesis of Representative Snowmobile Component Noise Sources into an Overall A-Weighted Noise Level

noise was the dominant noise source in snowmobiles. The noise spectrum of Figure 9 for a 1971 model shows that along with intake noise, the exhaust is the largest noise contributor. Recent improvement in exhaust mufflers and intake silencers have reduced the magnitude of this contribution as the data in Figure 10 for a 1973 model indicates.

Engine Noise

Engine compartment noise is composed of mechanical noise radiated from the engine surfaces, carburetor intake, cooling fan, muffler shell, and miscellaneous sources. All these sources are lumped together under the cowl or hood making up one of the three major noise sources.

Engine noise is produced primarily by vibration of engine surfaces as a result of combustion within the engine. Any parts attached rigidly to the engine also become radiating surfaces. Intake noise is created by combustion within the engine in the same manner as exhaust noise. Some of the acoustic energy thus created leaves the engine through the carburetor air intake. Muffler shell noise is due to vibration of the muffler shell as the exhaust gas pulses through it. Fan noise (associated with fans required to provide cooling air) is produced by turbulence created as the fan blades move through the air and the passage of the cooling air over local obstacles. The other noises created in the engine compartment are associated with vibrations of surfaces attached directly and indirectly to the engine.

Track Noise

Track noise is associated with the impact of hard surfaces striking each other. For example, as the track moves over the bogies, sprocket teeth on the bogies must alternately engage and disengage with the track, creating impact noise. The clanking of other metal parts in the suspension system also contributes to track noise.

5. SELECTED NOISE LEVELS

The data on noise levels for currently available snowmobiles – see Figure 4 – exhibits a great deal of scatter. A rational approach can be made to the discussion of present and future noise levels by focusing attention on a few representative levels. It has been decided, in consultation with EPA,[10] that three different noise levels will be examined based on the information and data supplied by the manufacturers. The three levels may be summarized as follows:

1. Typical level of currently available, quiet products
2. Level of quietest product in October 1975 that incorporates the most advanced technology
3. A level somewhere between the first two, if these two are widely divergent, that can be practically obtained using available technology by October 1975.

The first level is to be that of typical, currently available, quiet snowmobiles. Currently available products are defined as those that were being sold in April 1973 – the date that this study was initiated. This would be the 1973 model snowmobile. Level #1 indicates where the industry stood in terms of noise control technology at the start of this project.

The value of Level #1 may be determined from an examination of the noise data for existing snowmobiles shown in Figure 4. The mean level for all 215 models shown is slightly in excess of 81 dBA. However, if those models exceeding the New York State requirements of 82 dBA are not counted, the mean level is approximately 80 dBA. The models exhibiting noise levels less than about 78 dBA represent only about 5 percent of those for which data is available and hence are not typical. As a result, a typical quiet snowmobile, as sold in Aprii 1973, exhibits a noise level in the range 78 to 82 dBA, the mean being approximately 80 dBA. This is Level #1.

The second level will be that of the quietest model snowmobile that is expected to be available in October 1975, the anticipated effective date for Federal noise regulations and will consist of the 1976 model year for snowmobiles. This assumes one year for compliance with the regulations. In selecting the quietest 1976 snowmobile, some judgement must be used in selecting a model that fulfills the operational requirements of snowmobile users. That is, the machine must be of a popular size, have good performance characteristics and not be overly heavy. Not every quiet snowmobile can be considered as a candidate. Small, quiet machines that do not have sufficient speed or power, and large, heavy machines that tend to bog down in loose snow should not be considered because their performance characteristics have been radically changed, even though they may be very quiet. One 1974 model snowmobile has been measured and certified at 76 dBA. This model is a popular size in the range of 400 to 440 cc and weighs approximately 400 to 450 pounds. The manufacturer of this snowmobile has indicated that he anticipates a level of 74 dBA from this snowmobile for the 1976 model year (those made in 1975).[11]

Other manufacturers have indicated reasonable progress in noise control and it is likely that the 1976 model year will see many snowmobiles with noise levels as low as 74 dBA. There is no indication from any of the manufacturers that levels lower than this can be obtained. It seems quite reasonable then, that Level #2 should be 74 dBA.

The third level selected is to be between the first two if these are widely separated. Such a condition would indicate creative application of technology known only to some manufacturers. Since not all manufacturers could comply with a regulation set at Level #2, Level #3 is proposed as an intermediate level.

Clearly, not all snowmobile manufacturers will be able to comply with a 74 dBA noise level by 1976 even though several will be able to do so. A value for Level #3 chosen somewhere between 74 dBA and 80 dBA would insure a greater degree of compliance among manufacturers. The International Snowmobile Industry Association (ISIA) has proposed 78 dBA for the 1976 model year. This organization includes in its membership 18 major snowmobile manufacturers accounting for approximately 90 percent of all snowmobiles manufactured. It is the opinion of Wyle Research, based on information supplied by manufacturers and our own engineering experience in noise control, that a reasonable level for the 1976 model year would be 76 dBA. Without relying on new technology, manufacturing firms representing approximately 60 percent of the market should have the capability of complying with a 76 dBA level for 1976. All three levels that have been discussed are summarized below in Table 3.

Table 3

Selected Noise Levels for Potential Noise Regulation of Snowmobiles

Level	Interpretation	Value
1	Currently Available Snowmobile Levels	80 dBA
2	Quietest Snowmobile October 1975	74 dBA
3	Practically Attainable Level by October 1975	76 dBA

6. NOISE REDUCTION TECHNIQUES AND COSTS

In Chapter 5, three selected noise levels were developed for snowmobiles. This chapter will discuss existing technology for reducing noise from individual snowmobile noise sources. The cost of applying this technology to achieve the three selected noise levels will then be presented.

The terms of this study emphasize cost to the manufacturer as an important consideration. The data collection effort was structured to be consistent with this requirement — requesting data for a variety of noise abatement measures from the manufacturer. In some instances, manufacturers furnished the information requested; in others, however, they supplied a variety of direct and indirect cost elements which they expect to incur. In all cases, manufacturers supplied cost data for noise reduction to discrete levels, in particular, 78 dBA, 76 dBA, 75 dBA and 73 dBA, since these four levels have been attained or have been proposed by various regulating agencies as reasonable levels for snowmobile noise emission.

Three observations are appropriate for the proper interpretation of the data presented. The first problem requiring explicit exposition is the relationship between direct expenditures incurred by manufacturer in noise abatement endeavors and the accounting practices associated with these expenditures. The recording and burdening of direct cost varies among suppliers according to their cost accounting systems and cannot be specified in a general sense. Furthermore, in cases where tooling and design expenditures are involved, the specific unit cost will depend on the expected production runs for the model under consideration, a variable which might change considerably over time.

For these reasons, a definitive, defensible overall relationship between "cost to manufacturer" and "cost to the consumer" is difficult to establish. However, in certain instances where only consumer costs were provided, such a relationship must be assumed. Although manufacturing overhead, general and administrative expenses, distributor and retailer markups customarily increase consumer prices many times the direct cost of production, the competitive characteristics of the snowmobile industry limit somewhat the total increase in cost to the consumer. Manufacturers who submitted both manufacturers and consumers cost information showed a difference between the two costs ranging from a factor of 2 to a factor of 3. Therefore, when only consumer costs were available, the manufacturing costs were assumed to be smaller by a factor of 2.5.

The second observation is the obvious limitation of some of the data provided by manufacturers. Snowmobile manufacturing firms display a wide range of organizations. At one end of the spectrum are firms with large engineering departments staffed with noise specialists capable of using sophisticated equipment for making noise measurements, as well as evaluating the effectiveness of new noise reduction techniques. The other end of the spectrum is populated with small firms who cannot afford to allocate funds for engineers trained in noise control and special noise measuring equipment. Obviously, with such differing capabilities in noise control, the data supplied by the manufacturers varied from empirical results to well-substantiated engineering projections to mere conjecture. Accordingly, an attempt was made to separate all data into two groups; those based on good engineering practice and those based on conjecture.

All noise levels in this report are assumed to be median levels for each production run. That is, there is a normal spread in the levels produced by all the machines in each model line. Due to a lack of data, the magnitude of this spread is not accurately known, but it seems reasonable to assume it is about 4 dB wide and centered about the median. Thus for all models (at least 90 percent) to be below a particular level, the design goal will have to be depressed by 2 dB.

All estimated costs contained in this report correspond to this median level. Any depression of the noise level goal will, of course, be reflected in proportionally higher costs.

All estimated costs also assume adequate development time as discussed under a separate heading.

Noise Reduction from Subsources

There are two basic approaches to any noise reduction problem; one is to control noise at its source by appropriate engineering methods, the other is to prevent transmission of noise, once it is created, by interruption of the transmission path with barriers or enclosures. Some noise sources are more amenable to the first technique, some to the second, and some to a combination of the two.

The following discussion is not intended to be a definitive engineering guide to snowmobile noise control, but is merely a summary of some of the available techniques and methods that may find practical application in snowmobile noise reduction. It is important to realize that reduction of overall noise levels will be accomplished only when all contributing noise sources are treated. For example, the 1973 model snowmobile outlined in Figure 10 was fitted with a new stock muffler system designed for production. The new muffler reduced exhaust noise from 74 to 68 dBA, but the measured overall noise level was reduced only 0.5 dB from 81.5 to 81 dBA. This is due to the manner in which acoustic energy from multiple sources combines.

Engine Compartment Noise

Engine compartment noise includes all the noise sources under the hood producing levels in the order of 85 dBA. The hood provides an approximate attenuation of only 5 dB due to poor sealing and the presence of large cooling air louvers. A well designed hood should be capable of attenuating the interior noise by 10 dB. This source of noise may be reduced by applying both general methods of noise reduction; the sources in the compartment may be quieted and the attenuation of the hood may be improved.

The major difficulty in improving hood attenuation is the requirement for cooling air which is essential for safe operation. The need for adequate engine cooling is a legitimate design constraint. Fan-cooled engines allow for more complete hood enclosures than do forced air engines (used for high speed machines and racers) which do not use a fan at all. It seems unlikely that the present concept of a Free Air Snowmobile is compatible with noise emission below 80 dBA. Fan-cooled engines are more amenable to noise control than are free air engines, since the engine compartment hood may be more fully enclosed.

A third type of engine which is water cooled has better possibilities still, even though it requires a cooling fan since the engine compartment may be fully enclosed. It has been estimated by some manufacturers that the cost to change from an air-cooled to a liquid-cooled engine would be in the range of $30.

If an air-cooled engine is retained, a cost of approximately $7 per machine would be incurred to improve the hood sealing and secure open-cell polyurethane foam absorption material to the interior. In addition, air cooling louvers can be of a minimum size that will provide sufficient air flow for cooling. Judicious placement of the louvers so that noise radiating from them is directed downward as much as possible will help reduce operator exposure levels as well as exposure levels for distant observers. It may prove to be practical to utilize acoustical louvers that are acoustically absorptive on the interior side so as to allow free air passage in one direction while blocking noise propagating in the other. Such louvers are now in common use for noise reduction in mechanical equipment, but should be considered advanced technology for snowmobiles.

Within the engine compartment several noise sources can be quieted; including the engine, the cooling fan, the muffler shell, and the carburetor intake. The engine can be mounted on vibration control mounts of a proper size corresponding to the weight and vibration frequency of the engine. In a recent study of quiet snowmobiles, some success in reducing induced vibration was achieved by coating the engine compartment floor and frame members with automotive cork-filled undercoat material.[12]

The cooling fan can be chosen for quiet operation. Fan noise technology is well advanced and manufacturers can make use of this technology described in the noise control literature. The quietest fan for any application is the one that operates near peak efficiency and cooling fans should be selected with this in mind. The cooling air can be ducted in and out with absorptively lined ducts to decrease radiated noise. Again, technology for quiet air flow ducting is established and well documented in the literature.

Muffler shell noise presents some unique problems. Some manufacturers have reduced this noise by wrapping the muffler with an absorptive material (such as fiberglass) covered with sheet metal, but others claim that using space for a large muffler would lead to overheating in the engine compartment. Still others have placed a wrapped muffler outside the engine compartment, but there are those who maintain that an external muffler will melt snow and the resulting water will refreeze on other parts of the snowmobile. A valid suggestion made by an independent research group is to use a flexible exhaust pipe or flexible connections to isolate the muffler from the rest of the engine compartment.[13] This will reduce noise to a certain degree by reducing the vibration of other components.

Carburetor intake noise has been quieted to some extent in the last few years by addition of intake silencers. Intake noise is less important now than other engine compartment sources. The technology for improving the efficiency of intake silencers is available and the cost to install an improved silencer necessary to reduce intake noise would range from $4 to $8.

Exhaust Noise

Exhaust systems are currently available which utilize an expansion chamber incorporated in a tuned system. This configuration helps to scavenge spent gases from the engine and so is more efficient than a conventional muffler (or no muffler) both for noise suppression and power output. Exhaust noise is no longer a major contributor to overall noise due to the widespread use of tuned exhaust systems. Exhaust noise levels on the order of 68 dBA are feasible and an estimated manufacturers cost for the addition of a system to achieve such a level is approximately $13.

Track and Suspension Noise

Noise produced by the track and suspension system can only be reduced through design since baffling techniques are not practical. Track and suspension noise is currently on the order of 73 dBA, although some manufacturers have reduced track noise below this level. A widely held belief is that track noise is the "noise floor" for snowmobiles and is not amenable to treatment. There seems to be some contention as to just where this floor is, however. One manufacturer performed tow-by tests without the engine running and reported passby levels of 74 dBA in grass and 63 dBA is snow. Another manufacturer engaged a private engineering firm to study the basic sources of snowmobile noise. Their tests indicated that track noise was on the order of 62 dBA in grass. Still another manufacturer has indicated that it should be feasible to reduce track and suspension noise to a level necessary to meet an overall noise level of 73 dBA. An estimated cost for this engineering work is approximately $6 per machine.

Operator Noise Exposure

It should be noted that working on the problem of reducing operator noise exposure will benefit efforts to reduce noise levels measured at 50 feet. The converse is not always true, however, since by changing the vehicle's noise directivity pattern, levels measured at 50 feet may be reduced without reducing levels at the operator's ear position. An example of this would be installation of noise baffles causing the sound to be directed to the front and to the rear of the snowmobile. Levels measured in accordance with the SAE J192 standard may then be reduced without a corresponding reduction in the noise levels at the operator's position.

The benefits of reducing operator noise exposure are substantial and since reductions in levels at 50 feet accompany reductions in levels at the operator's position, it would seem that industry's efforts should be aimed at reducing operator noise level. However, as discussed in the section on Operator Noise Exposure, techniques for measuring noise at the operator's position are not well defined. So until standard measurement procedures are developed, noise control efforts will have to be directed towards reducing noise levels at 50 feet.

Achievement of the Selected Noise Levels Through Application of Noise Reduction Techniques

The previous discussion of techniques to reduce noise emitted from various sources has focused on reducing mechanical, intake, exhaust and track noise. The noise control cost information developed for these subsources can now be combined to determine the total costs of noise reduction to the three selected noise levels developed in Chapter 5.

Table 4 shows the estimated manufacturing cost increases along with the required modifications to reduce overall noise to each of the three levels. The data shown are estimates made by Wyle Research, based on data supplied by some of the manufacturers in Group 1 (Large Manufacturers). The manufacturers who supplied component cost data represent about 34 percent of the snowmobile market. This 34 percent of the market may be considered as representative of the industry as a whole since the total machine costs in Table 4 compare very well with total machine costs presented in Figures 11 and 12 and Table 5 which are based on information supplied by manufacturers representing 70 percent of the snowmobile market.

All manufacturing costs in Table 4 are given for each noise control component or required work necessary to reduce noise to the level shown. For Levels #2 and #3, two alternatives are considered – retainment of air-cooled engines or changeover to liquid-cooled engines. The liquid-cooled engine is not considered to be an economically valid alternative for reduction to Level #1 – 80 dBA. Rotary engines were not considered as viable alternatives to reciprocating-piston engines due mainly to a lack of data. Although some manufacturers have indicated that rotary engines are quieter than reciprocating piston engines, there has been no demonstration that they possess appreciable advantage over reciprocating-piston engines for noise control purposes.

Many manufacturers supplied data in the form of total cost per machine. This data is presented in Figures 11 and 12 for Groups 1 and 2 respectively. All costs are given for reduction of noise with a baseline reference of 82 dBA. There is a great deal of variation in the estimated costs anticipated by various manufacturers and the spread in the estimates for each noise level tends to increase as the level gets progressively lower.

Table 4

Estimated Per-Machine Manufacturing Cost Increases for Noise Reduction in Snowmobiles

Component	Selected Noise Level / Engine Alternate / Required Work or Component	#1 80 dBA	#2 74 dBA		#3 76 dBA	
		Air Cooled	Air Cooled	Liquid Cooled	Air Cooled	Liquid Cooled
Engine Compartment	Engine Modifications	$ 6	$55	$32	$20	$32
	Intake Silencer	$ 4	$ 8	$ 8	$ 8	$ 8
	Acoustic Treatment of Console and Hood	$ 7	$ 4	$ 4	$ 4	$ 4
	Air Ducts and Baffles	N.R.	$ 4	N.R.	$ 4	N.R.
Exhaust	Improved Muffler	$ 5	$13	$13	$13	$13
Track and Suspension	Isolation of Axles	N.R.	$ 4	$ 4	N.R.	N.R.
	Track Redesign	N.R.	$ 2	$ 2	N.R.	N.R.
TOTAL COST		$22	$90	$63	$49	$57

[1]The costs presented are estimates to reduce the noise from a model line to an average value as indicated. Data is based on information from manufacturers representing 34 percent of the snowmobile market. All component cost data shown in Table 4 was supplied by firms in Group 1 (Large Manufacturers).

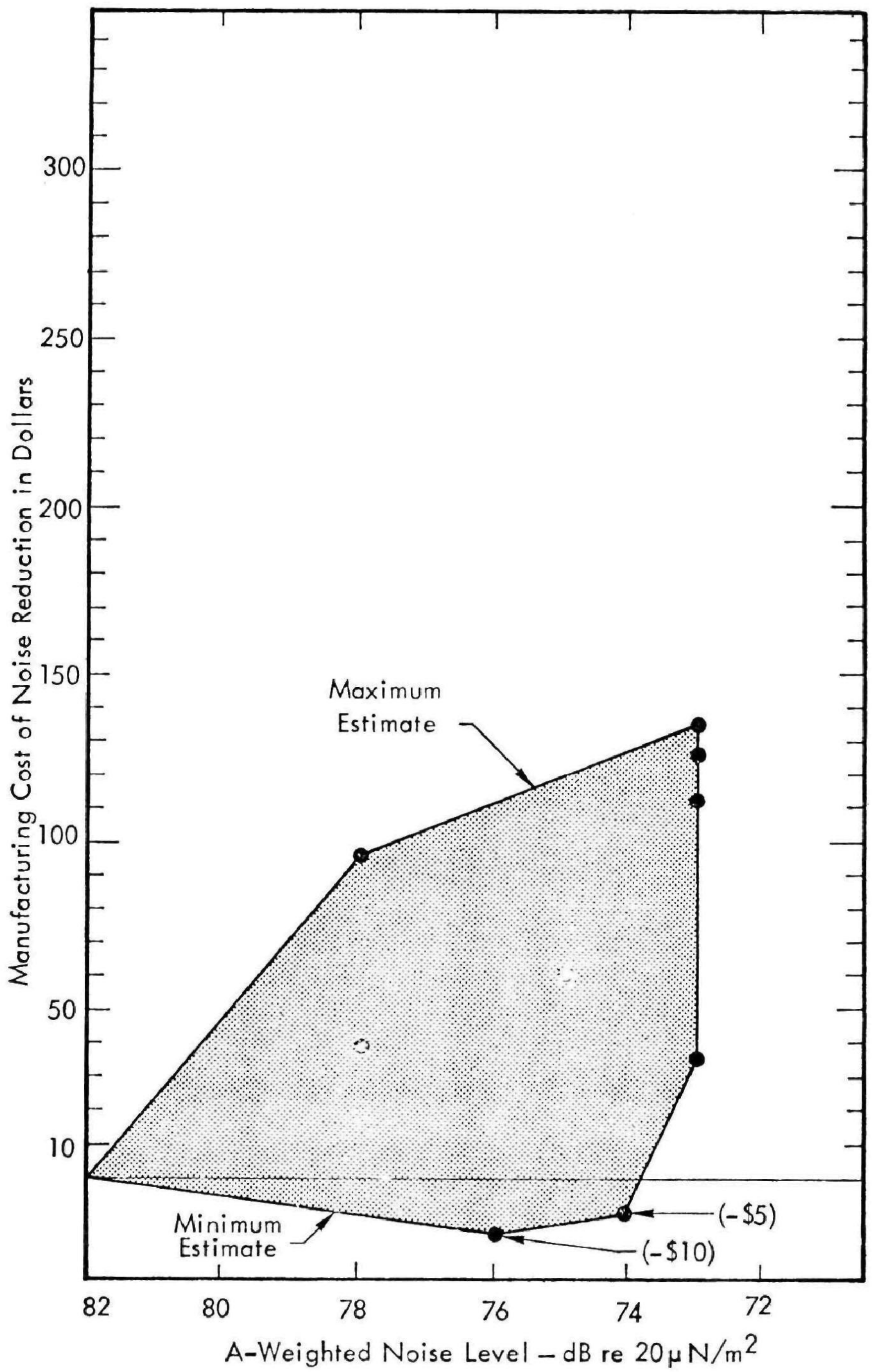


Figure 11. Estimated Manufacturing Costs for Snowmobile Noise Reduction as a Function of Level Obtained (Costs are Based on Noise Reductions from 82 dBA) (Group 1 – Large Manufacturers)

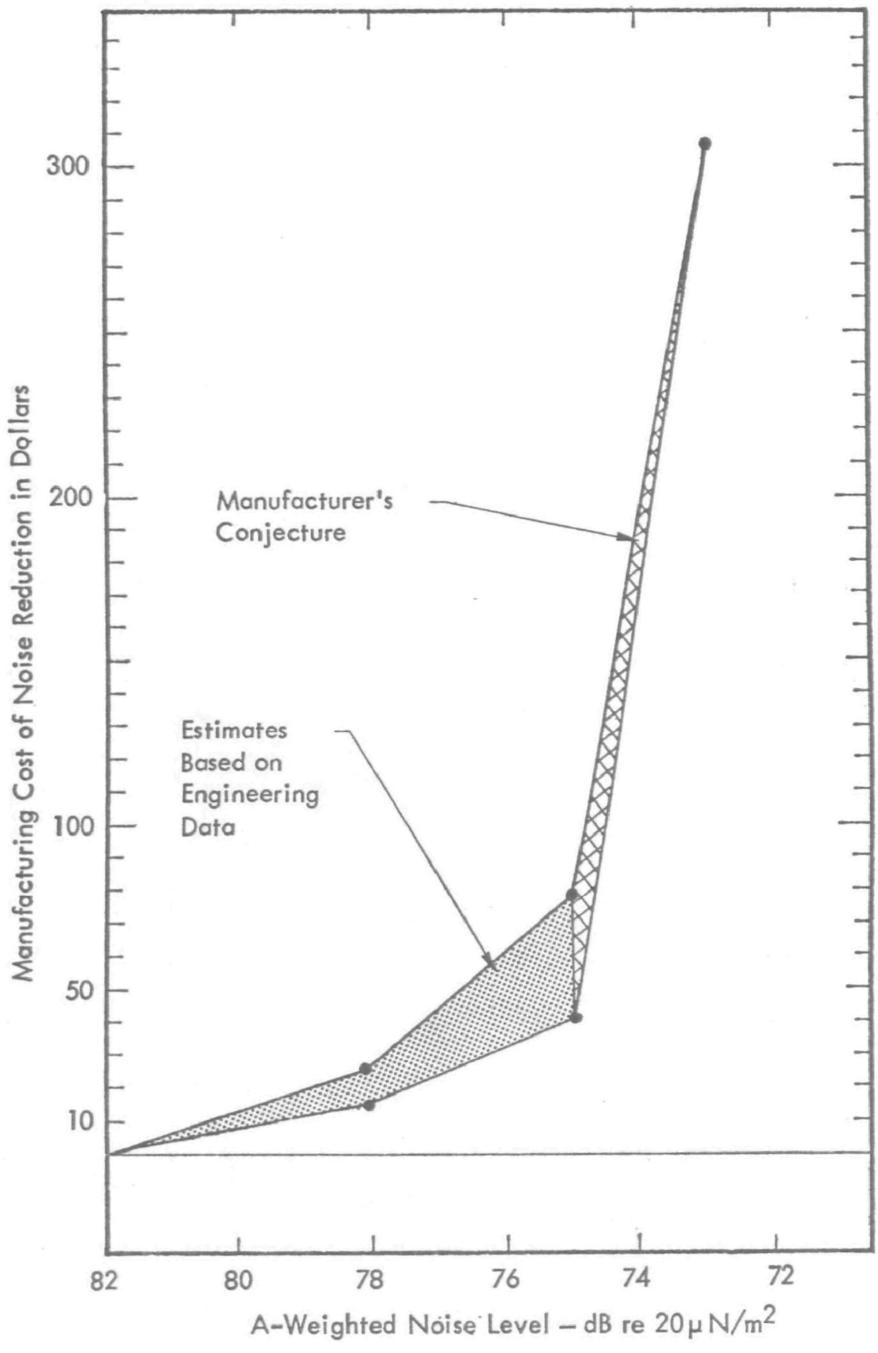


Figure 12. Estimated Manufacturing Costs for Snowmobile Noise Reduction as a Function of Level Obtained (Costs are Based on Noise Reductions from 82 dBA) (Group 2 – Small Manufacturers)

It is interesting that one manufacturer did, in fact, save money in the process of quieting his snowmobile. These data points represent actual costs incurred. It should be noted that this is a manufacturing cost saving only in the context of a noise reduction from 82 dBA to 78 dBA. After spending $26 per unit to reduce noise from 86 dBA to 82 dBA, a change in the design of the intake silencer system resulted in lower cost and a quieter machine. It is not expected that other manufacturers would be capable of similar cost savings, but this isolated case does indicate that making a snowmobile quieter is not always associated with a manufacturing cost penalty.

A summary of the costs involved to reduce noise to the three levels discussed in Chapter 5 is shown in Table 5. These costs were determined by calculating the average value of the shaded portion of the graphs in Figures 11 and 12 at each of the three levels of interest. The costs in Table 4 are direct manufacturing costs in dollars.

The data shown in Table 5 are, in the opinion of Wyle Research, accurate estimates of costs that would be incurred to reduce noise to the indicated levels. The $180 cost for reduction to 74 dBA may be high, but is probably a direct reflection of the approach to noise reduction being used by the smaller firms in Group 2.

Basic engineering and design changes are likely to be favored as a noise control approach by the larger firms in Group 1. These changes are initially expensive for the first few stages of reduction, but get progressively less expensive at the more advanced stages. The technique of absorbing or shielding noise, once it is created, is probably the only approach a smaller firm can adopt because of its limited resources. This technique is initially inexpensive for small stages of reduction, but as the target noise level gets lower, this "band-aid" approach becomes very expensive. Hence, as seen in Table 5, Group 2 manufacturers incur a lower cost for reduction to Level #1 – 80 dBA than do Group 1 manufacturers. For a reduction to Level #3 – 76dBA, both groups would incur about the same cost whereas for a reduction to Level #2 – 74 dBA, it would be much more costly for the Group 2 manufacturers than for the Group 1 manufacturers. The costs given in Table 5 for Group 1 compare favorably with the

Table 5

Summary of Estimated Noise Reduction Costs for Snowmobiles[1]

Level	Noise Level Goal	Group 1	Group 2
1	80 dBA	$22 (2%)[2]	$ 9 (1%)
2	74 dBA	$86 (8%)	$180 (16%)[3]
3	76 dBA	$52 (5%)	$ 45 (4%)

[1]Based on information supplied by manufacturers representing 70 percent of the snowmobile market. Costs are estimates to reduce noise from a model line to an average value as indicated.

[2]Numbers in parentheses are percentage increases based on an average retail price of $1146.

[3]The $180 cost anticipated for Group 2 for reduction to 74 dBA is based on data from one manufacturer. It was considered to be a guess as opposed to an estimate based on engineering data.

component cost totals given in Table 4 and they are more representative of the industry as they were compiled from information supplied by manufacturers representing 70 percent of the snowmobile industry.

Weight Increases Due to Noise Reduction

Weight increases are very important to snowmobile manufacturers because of snow flotation problems discussed in Chapter 4. Overly heavy machines may bog down in loose snow and hence present a hazard where snow conditions change from hard-packed snow to loose powder. Most popular sized snowmobiles weigh between 300 and 450 pounds with an average weight of 398 pounds.

Added weight due to noise reduction is first evident in the form of added silencing equipment such as mufflers and intake silencers. Additional silencing may require heavier engine compartment panels and heavier engine mounting frames.

Weight increases attributable to noise reduction are shown in Figures 13 and 14 for all manufacturers in Groups 1 and 2. Again, there is a wide spread in the data at each noise level and the spread tends to increase as the level decreases.

In general, each decrease to a level below 82 dBA is accompanied by an increase in weight. There was one response, however, that indicated a noise reduction with no weight penalty. A weight increase was encountered to reduce noise from 86 dBA to 82 dBA, but for the reduction from 82 dBA to 76 dBA, no extra equipment was added.

Table 6 indicates the median level of weight increases as a direct result of noise reduction techniques. The data taken as median values from the graphs in Figure 13 and 14 is given in added pounds and in percent increases in weight based on an average snowmobile weight of 398 pounds.

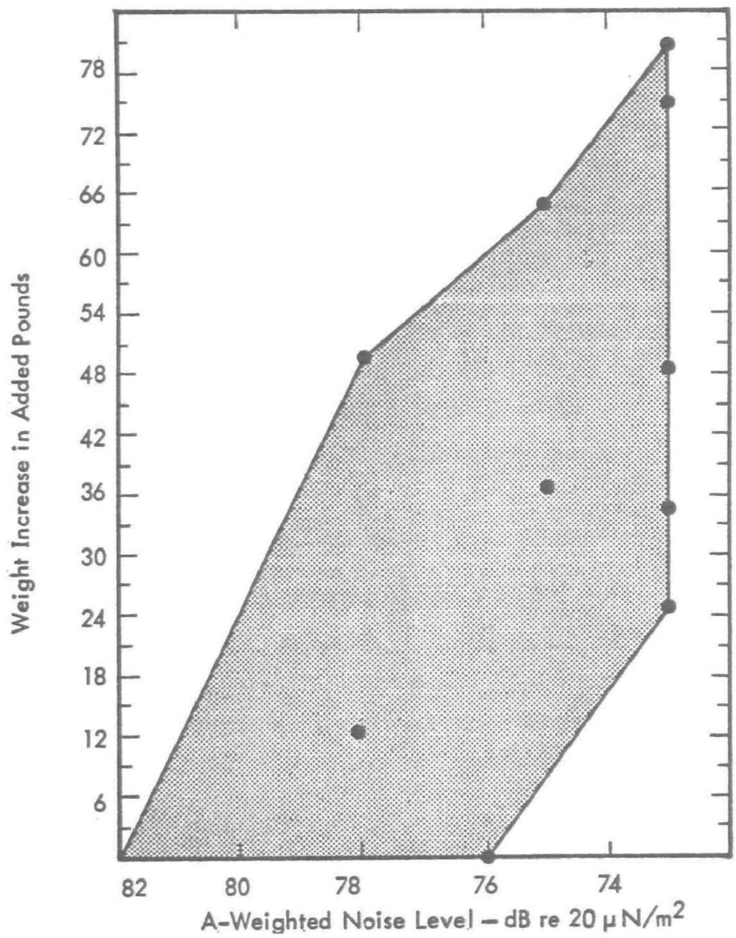


Figure 13. Estimated Snowmobile Weight Increase Due to Noise Reduction Equipment (Data Based on Noise Reduction from 82 dBA)

(Group 1 - Large Manufacturers)

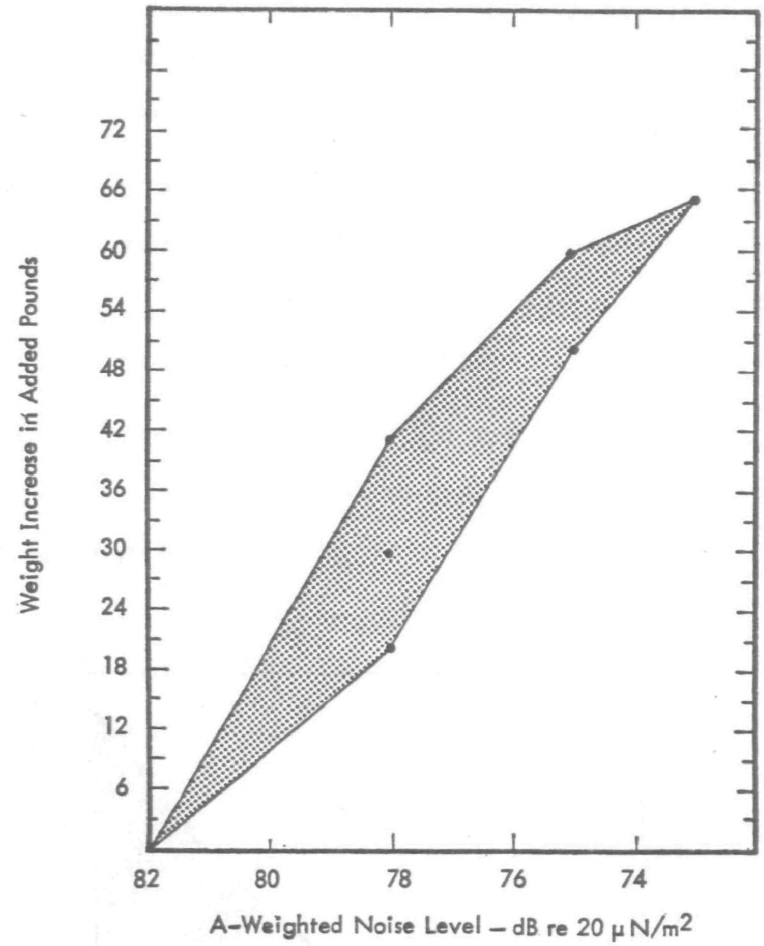


Figure 14. Estimated Snowmobile Weight Increase Due to Noise Reduction Equipment (Data Based on Noise Reduction from 82 dBA)

(Group 2 - Small Manufacturers)

Table 6

Estimated Snowmobile Weight Increase Due to Noise Reduction[1]

Level	Noise Level Goal	Group 1	Group 2
1	80 dBA	12 (3%)[2]	15 (4%)
2	74 dBA	52 (13%)	61 (15%)
3	76 dBA	30 (8%)	48 (12%)

[1]Based on information supplied by manufacturers representing 70 percent of the snowmobile market.

[2]Numbers in parentheses are percentage increases based on an average weight of 398 pounds.

Lead Time Requirements

One of the major difficulties in a product noise reduction program is lead time — the time required for engineering, testing and tooling. During the data gathering phase of this study, manufacturers were asked to comment on their lead time requirements. Most manufacturers indicated the necessity of having sufficient lead time and several firms supplied lead time schedules. The schedules submitted varied widely due to different levels of effort that individual firms thought were necessary for noise reduction modifications. Manufacturers who anticipated major engineering and design changes indicated long lead time requirements and those who did not anticipate major changes indicated shorter requirements. The typical lead time schedule discussed below is, in the opinion of Wyle Research, adequate for noise reduction efforts to reach a goal of 76 dBA (Level #3 as discussed in Chapter 5). Of course, if lower noise levels are required, the necessary lead time will increase appropriately. The schedule is based on information supplied by snowmobile manufacturers representing approximately 43 percent of the snowmobile industry.

Sales for the 1976 model year snowmobile will begin in June of 1975 for most firms. The machines will be produced throughout most of 1975 with an average production start date of March 1975. The average time period required for tooling and testing is 9 months so engineering efforts will be frozen in June 1974. Any engineering work required for noise reduction will have to be accomplished before this date. However, as seen in Table 4, major engineering changes will not be required for a reduction to 76 dBA. But, if manufacturers are required to reduce noise levels below 76 dBA, major engineering work will be required and the needed development time will exceed the time available in this schedule.

It was estimated in Chapter 5 that manufacturing firms representing approximately 60 percent of the snowmobile market have the capability of complying with a 76 dBA level within the estimated lead time schedule. If the effective date for regulation of snowmobile noise is extended from October 1975 to October 1976, then the percentage of manufacturers who will be able to comply will increase. It is estimated that at least 80 percent and perhaps as much as 90 percent of the market will be able to comply with a 76 dBA level with one extra year for development.

7. RECOMMENDATIONS FOR FURTHER WORK

As a result of this study, it was determined that further research is needed in the following areas:

- The SAE J192 test procedure needs to be reviewed for applicability as a regulatory tool. The SAE Subcommittee for Motorized Snowvehicles is presently working on new revisions. One major question that needs to be settled is the test surface to be used. One test surface must be found that gives accurate, repeatable results and is available to all manufacturers for a sufficient number of testing days.

- A study is needed to determine if any correlation can be established between operator noise levels and levels at 50 feet. If no correlation exists, then consideration should be given to a procedure for accurately determining noise levels at the operator's position. Regulations to maintain operator noise exposure within acceptable limits should then be considered.

- Research on typical use cycles of snowmobiles is needed to develop a data bank that accurately reflects the typical noise exposure of snowmobile operators.

- Research on the variance in noise levels for snowmobiles in each model line is required to determine the actual distribution of noise levels. Such information would be helpful in determining the anticipated compliance with noise level regulations.

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APPENDIX A

Snowmobile Manufacturers Contacted for This Study

Alouette
Featherweight Corporation
Montreal 364 Quebec, Canada

Alsport, Inc.
84 Whittlesey Avenue
Norwalk, Ohio 44857

Arctic Enterprises, Inc.
Box 635
Thief River Falls, Minnesota 56701

Auto Ski, Inc.
P.O. Box 97
Levis, Quebec,

Autotechnic Inc. - Ski-Zoom
2300 LeMire Blvd - Drummondville
P.Q., Canada

Boa-Ski., Inc.
P.O. Box 460
La Guadaloupe
Frontenac County, P.Q., Canada

Bombardier Ltd. (Ski-Doo/Moto-Ski)
Valcourt
P.Q., Canada

Brutanza Engineering
P.O. Box 158
Brooten, Minnesota 56316

Chaparral Industries
Denver,, Colorado 80216

Coleman Skiroule
Route 13
Wickham, Quebec, Canada

Columbia Div. of MTD Products Inc.
5389 West 130th Street
Cleveland, Ohio 44111

John Deere & Co.
John Deere Horicon Works
Horicon, Wisconsin

Fun Seasons, Inc.
1200 Riverwood Drive
Burnsville, Minnesota 55337

Gilson Snowmobiles
Road America Grounds
Elkhart Lake, Wisconsin

Griswold Swinger
1212 Chestnut Avenue
St. Paul, Minnesota 55403

Harley-Davidson Motor Co., Inc.
3700 West Juneau Avenue
Milwaukee, Wisconsin

Herter's Inc.
Plant 1
New Richland, Minnesota 56072

Jac-Trac Inc.
Route 2
Marshfield, Wisconsin 54449

Lori Engineering Corporation
Old Turnpike Road
Southington, Connecticut 06489

Massey-Ferguson, Inc. (Ski-Whiz)
1901 Bell Avenue
Des Moines, Iowa 50315

Melvin Manufacturing Company
Dryden, Maine 04225

Mercury Marine
Fond Du Lac, Wisconsin

Moto-Kometik, Inc.
P.O. Box 490
St.Jean Port-Joli, Quebec, Canada

Northway Snowmobile Ltd.
100 Hymus Blvd.
Point Claire, Quebec, Canada

OEM Ltd.
584 Clinton Avenue
Sudbury, Ontario
Canada

Ontario Drive and Gear, Ltd.
P.O. Box 280, Bleams Road
New Hamburg, Ontario, Canada

Outboard Marine Corporation
4143 North 27th Street
Milwaukee, Wisconsin 53216

Polaris
Roseau, Minnesota

Leisure Vehicles, Inc. (Raider)
2766 Elliott
Troy, Michigan 48084

Raybon Manufacturing Company, Inc.
25 George Street
Wallingford, Connecticut 06492

Roll-O-Flex
Regina, Saskatchewan, Canada

Rupp Industries, Inc.
1776 Airport Road
Mansfield, Ohio 44903

Scorpion
Crosby, Minnesota 5644

Sno-Jet, Inc.
P.O. Box 246 - Ouellet Blvd.
Thetford Mines
P.Q., Canada

Speedway, Inc.
160 E. Longview
Mansfield, Ohio 44905

U.S. Sports
Riverside Airport
Marcy, New York

U.S. Suzuki
Santa Fe Springs, California 90670

Yamaha International Corporation
6600 Orangethorpe Avenue
Buena Park, California 90620

APPENDIX B

Design Features, Retail Costs and Measured Noise Levels for 1973 Snowmobile Models[1]

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Alouette	Mini-Brute	209 cc	5	3600	115	399	N/A
	Sno Duster	295 cc	20	6500	337	699	82
	Escort I	292 cc	22	6500	340	849	82
	Escort II	291 cc	22	8000	340	949	82
	Venture 440	436 cc	30	6500	410	1295	83
	Eliminator 295	291 cc	24	8000	363	1049	82
	Eliminator 340	338 cc	28	8000	363	1149	83
	Eliminator 440	435 cc	35	8000	368	1249	83
	Sno Brute 340	338 cc	28	8000	377	1279	83
	Sno Brute 440	436 cc	40	8000	390	1379	83
Alsport	MTS-30	165 cc	3	3600	125	299	N/A
	TS-50	200 cc	5	3600	145	445	N/A
	TS-100	200 cc	5	3600	155	495	N/A
	TS-100L	200 cc	5	3600	155	535	N/A
	TS-125	246 cc	7	3600	160	549	N/A
	TS-125L	246 cc	7	3600	160	589	N/A
	TS-150	230 cc	14	5900	240	679	N/A
	TS-290	290 cc	21	6500	255	745	N/A
	STS-290	290 cc	21	6500	260	825	N/A
	STS-340	340 cc	26	6500	260	805	83.7
Arctic	Lynx 292	292 cc	19	6000	N/A	795	83.8
	El Tigre 250	245 cc	N/A	7500	365	1275	N/A
	El Tigre 340	339 cc	37	7500	365	1350	81.7
	El Tigre 400	398 cc	43	7500	365	1425	82
	El Tigre 440	436 cc	47.5	7500	370	1495	81.7
	Puma 440	436 cc	N/A	6500	365	1250	N/A
	Cheetah 340	339 cc	31	6500	375	1185	80
	Cheetah 400	398 cc	N/A	6500	375	1295	80.5
	Cheetah 440	436 cc	37	6500	375	1375	81
	Panther 295	294 cc	19	6500	385	1325	78.7
	Panther 340	339 cc	31	6500	385	1250	79.0
	Panther 400	398 cc	N/A	6500	385	1350	81.5
	Panther 440	436 cc	37	6500	385	1425	80.5

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Auto Ski	Midget 225	225 cc	15	5500	325	N/A	N/A
	Midget 290 SGL	293 cc	20	5500	350	N/A	75.6
	Midget 290 TWN	290 cc	22	6500	350	N/A	75.6
	Bonanza 290	290 cc	N/A	N/A	350	N/A	N/A
	Bonanza 340	338 cc	28	7200	355	N/A	80
	Bonanza 440	436 cc	35	6500	355	N/A	79.5
	Spitfire 290	290 cc	N/A	N/A	355	N/A	N/A
	Spitfire 340	338 cc	N/A	N/A	365	N/A	N/A
	Spitfire 440	431 cc	N/A	N/A	365	N/A	79.5
	Spitfire SS 440	436 cc	36	6500	375	N/A	79.5
	Mach 340	338 cc	55	9500	N/A	N/A	80
	Mach 440	431 cc	70	9500	N/A	N/A	N/A
	Mach 650	647 cc	110	9500	N/A	N/A	N/A
Autotechnic	Rebel 280	280 cc	16	5500	270	665	84
	Rebel 290	290 cc	19.5	5500	275	775	82
	Rebel 290e	290e cc	19.5	5500	300	895	82
	Comet 293	293 cc	24	7200	275	995	82
	Comet 340	340 cc	28	7200	280	1095	83
	Comet 440	440 cc	35	7000	285	1195	N/A
	Comet 441	441 cc	38	7000	285	1225	N/A
	G.T. 440c	440 cc	40	7000	340	N/A	N/A
Brutanza	LC 44	439 cc	50	6500	395	1745	82
	LC 29	294 cc	30	6000	355	1495	82
Chaparral	Firebird 250	242 cc	22	7500	310	895	81.1
	Firebird 295	292 cc	26	7500	320	995	80.9
	Firebird 340	338 cc	31	7500	330	1099	80.6
	Firebird 400	394 cc	36	7500	335	1195	81.7
	Firebird 440	432 cc	39	7500	340	1375	81.5
	Thunderbird 340	338 cc	31		340	1245	81.9
	Thunderbird 440	432 cc	39		360	1399	82
	SSIII 340	338 cc	35	7500	320	1245	82
	SSIII 400	394 cc	42	7500	330	1345	82
	SSIII 440	432 cc	46	7500	335	1425	81.9
Coleman Skiroule	RT 300	293 cc	19.5	5500	354	799	83.2
	RT 300E	293 cc	19.5	5500	382	899	83.2
	RT 300T	291 cc	24	7000	360	999	80.6
	RT 340	338 cc	28	6000	360	1099	77.9

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Coleman Skiroule (continued)	RT 440	437 cc	35	6000	402	1249	82.1
	RT 440E	437 cc	35	6000	430	1349	82.1
	RTX 300	293 cc	24	6000	356	1049	83
	RTX 340	338 cc	34	6500	362	1199	82.7
	RTX 440	437 cc	40	6500	374	1299	80.6
	RTX 447	437 cc	40	6500	404	1399	80.6
	RTW 300	294 cc	23	6000	356	1299	77.4
Columbia/ MTD	340	339 cc	30	7000	356	1095	N/A
	400	398 cc	34	7000	358	1175	N/A
	440	428 cc	38	7000	358	1245	N/A
John Deere	400	339 cc	28	6750	382	1235	81.9
	500	436 cc	36	6750	386	1335	81.7
	600	436 cc	36	6750	410	1435	81.9
	JDX4	292 cc	25	6750	396	995	81.7
	JDX8	438 cc	40	6750	386	1435	81.7
Evinrude	Bobcat SS 30	399 cc	30	6000	N/A	1075	83.7
	Bobcat SS 32	437 cc	32	6000	N/A	1145	82.8
	Norseman 21	399 cc	21	6000	N/A	855	82.9
	Norseman 27	437 cc	27	5800	N/A	995	82.4
	Norseman 30	437 cc	30	6000	N/A	1275	83.7
	Trailblazer 30E	437 cc	30	5800	N/A	1525	83.1
	TW 30Q	437 cc	30	5800	N/A	1695	74.8
	RC-35Q	528 Rotary	35	5500	520	1700	77.4
Feldman Eng.	Snow Flake 400	340 cc	22.5	N/A	297	695	N/A
Fun Seasons	Sno-Blazer	292 cc	20	6000	225	895	82.4
Harley-Davidson	Y 398	398 cc	30	6000	400	N/A	81.7
	Y 440	433 cc	35	6000	400	N/A	81.6
JAC-TRAC	290	290 cc	24	6500	340	795	81.2
	399	399 cc	33	6500	340	995	81.7
	440	440 cc	38	6500	340	1095	82
	LTD 399	399 cc	33	6500	350	1195	81.7
	LTD 440	440 cc	38	6500	400	1300	82

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Johnson Motors	Golden Ghost 30	437 cc	30	5800	N/A	1695	73.8
	Phantom 35R	528 Rotary	35	5500	N/A	1850	N/A
	Rampage 30	399 cc	30	6000	N/A	1075	N/A
	Rampage 32	437 cc	32	6000	395	1145	N/A
	Reveler 21	399 cc	21	6000	N/A	855	N/A
	Reveler 27	437 cc	27	5800	N/A	995	N/A
	Reveler 30E	437 cc	30	6000	N/A	1275	N/A
	Skee Horse 30	437 cc	30	5800	N/A	1525	N/A
Kometik	MK-II-225	225 cc	12.5	5500	360	575	N/A
	MK-III-295	295 cc	20	5500	310	785	81.1
	MK-III-340	340 cc	25	6500	340	965	77.5
	MK-III-340	340 cc	28	6500	340	1045	78.7
	MK-III-440	440 cc	37	6500	340	1150	79.1
Massey-Ferguson	340T	339 cc	32	6500	355	N/A	80.7
	400T	398 cc	36	6500	360	N/A	81.9
	440T	428 cc	40	6500	365	N/A	82
	400 WT	398 cc	36	6500	385	N/A	81.9
	440 WT	428 cc	40	6500	390	N/A	82
Mercury Marine	Hurricane-Mark II	644 cc	50	6000	490	1610	83.6
	Hurricane-Mark I	644 cc	40	6000	584	1495	83.6
	440 Max-Electric	440 cc	40	6500	425	1245	79.7
	440 Max-Manual	440 cc	40	6500	395	1165	79.7
Moto-Ski	Cadet 250	247 cc	N/A	N/A	295	595	79
	Capri 295	293 cc	N/A	N/A	375	745	80.5
	Capri 340	336 cc	N/A	N/A	390	995	81.5
	Capri 440	435 cc	N/A	N/A	390	1095	81.5
	Zephyr 340	336 cc	N/A	N/A	420	1045	81.5
	Zephyr 440	435 cc	N/A	N/A	420	1145	81.5
	"F" 295	293 cc	N/A	N/A	380	1095	N/A
	"F" 340	336 cc	N/A	N/A	395	1145	N/A
	"F" 440	437 cc	32	6000	395	1245	82
	"S" 400	399 cc	N/A	N/A	400	1395	82
	"S" 440	437 cc	32	6000	400	1495	82
Northway Snowmobile	Explorer 15-340	339 cc	25	N/A	360	N/A	80.4
	Explorer 15-400	398 cc	30	N/A	360	N/A	N/A
	Explorer 15-440	436 cc	36	N/A	360	N/A	83

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Northway Snowmobile (continued)	Explorer 18-340	339 cc	25	N/A	375	N/A	80.4
	Explorer 18-400	398 cc	30	N/A	375	N/A	N/A
	Explorer 18-440	436 cc	36	N/A	375	N/A	83
	Interceptor 15-340	338 cc	36	N/A	365	N/A	80.4
	Interceptor 15-440	438 cc	43	N/A	365	N/A	83.5
	Interceptor 18-340	338 cc	36	N/A	380	N/A	80.4
	Interceptor 18-440	438 cc	43	N/A	380	N/A	82.6
	Interceptor 18-650	650 cc	55	N/A	385	N/A	83.2
Polaris	Colt 175	175 cc	12	N/A	286	N/A	79.5
	Colt 250	244 cc	20	N/A	300	800	82.2
	Colt 295	294 cc	22	N/A	330	N/A	81.7
	Colt S/S 295	294 cc	23	N/A	325	N/A	81
	Colt S/S 340	335 cc	25	N/A	330	N/A	81.1
	Charger 295	294 cc	22	N/A	390	1199	79
	Charger 400	398 cc	30	N/A	400	1250	80.5
	Charger 530	530 cc	42	N/A	410	1569	83.5
	Mustang 400	398 cc	30	N/A	453	1599	81
	Mustang 530	530 cc	42	N/A	463	1769	83
Raider	34TT	398 cc	32	6500	420	1199	79.9
	44TT	436 cc	40	6500	420	1399	81
Roll-O-Flex	Apache 338	338 cc	25	5500	320	N/A	81.5
	Apache 396	396 cc	28	5500	320	N/A	82.5
	Apache 433	433 cc	33	5500	320	N/A	82.7
	Comanche 292	292 cc	21	5500	295	N/A	81.3
	Cherokee 396	396 cc	28	5500	335	N/A	82
	Cherokee 433	433 cc	33	5500	335	N/A	82.5
	GT 292SS	292 cc	29	6500	320	N/A	81.5
	GT 338SS	338 cc	34	6500	320	N/A	83.5
	GT 433SS	433 cc	43	6500	320	N/A	83.8
Rupp	Sport 25	295 cc	25	6800	N/A	995	80.9
	Sport 30	340 cc	30	6800	N/A	1095	82
	American 305				N/A	1245	N/A
	American 40	440 cc	40	6600	N/A	1345	83.8
	American 40-E	440 cc	40	6600	N/A	1395	83.8
	Nitro 295	295S cc	N/A	7300	N/A	1150	82.6
	Nitro 340	340S cc	N/A	7300	N/A	1250	82.1
	Nitro 400	400S cc	N/A	7300	N/A	1350	82.6
	Nitro 440	440S cc	40	7200	410	1450	83.7

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Scorpion	Stinger 290	290 cc	22	6500	316	795	82.7
	Stinger 290 ET	290 cc	22	6500	311	N/A	82.7
	Stinger 340	339 cc	26	6000	325	895	83.8
	Stingerette	290 cc	22	6500	316	1045	82.7
	Super Stingerette	339 cc	26	6000	325	N/A	83.8
	Super Stinger 400 RV	398 cc	33	6500	358	1195	82.3
	Super Stinger 400 TK	398 cc	40	6800	358	1195	82.3
	Super Stinger 440	428 cc	42	6800	386	1295	83.1
Ski-Doo	Elan 250	246 cc	12	6000	265	795	82
	Elan 250E	246 cc	12	6000	301	N/A	82
	Elan 250T	247 cc	16	6000	270	N/A	N/A
	Elan 250SS	247 cc	22	6500	280	N/A	N/A
	Olympique 300	299 cc	15	6000	338	N/A	82
	Olympique 340	339 cc	23	6000	360	N/A	79
	Olympique 340E	339 cc	23	6000	360	N/A	79
	Olympique 400E	398 cc	27	6000	400	N/A	80.8
	Olympique 440	436 cc	28	6500	373	N/A	81
	Skandic 335	334 cc	20	6000	N/A	N/A	N/A
	Nordic 640ER				495	N/A	81.5
	T'NT 300T	293 cc		6000	375	N/A	79.3
	T'NT 340	339 cc	23	6500	390	1150	82
	T'NT 440	436 cc	28	6500	405	N/A	82
	Alpine 440R	436 cc	28	6500	548	N/A	78.3
	Alpine 440ER	436 cc	28	6500	584	N/A	78.3
	Alpine 640ER		28		610	N/A	81.8
	Valmont 440R	436 cc	28	6500	506	N/A	78.3
	Valmont 440ER	436 cc	28	6500	540	N/A	78.3
Sno-Jet	Star Jet 292	292Y cc	19	5500	328	859	80.2
	Star Jet 338	338Y cc	24	5500	350	999	79
	Star Jet 433	433Y cc	30	5500	350	1129	79.5
	SST 295	295S cc	27	6500	328	1049	80.1
	SST 340	340S cc	32	6500	350	1149	80.9
	SST 440	440S cc	38	6500	355	1299	80.7
	Whisper Jet	440Y cc	30	5500	408	1299	77.9
Speedway	340 Blue Max - FA[3]	340 cc	34	8500	330	1500	83.1
	440 Blue Max - FA	436 cc	61	8500	346	1600	84
	650 Blue Max - FA	650 cc	90	8500	370	1850	N/A

Manufacturer	Model	Engine Size	HP	Maximum RPM	Weight	Retail Price	Noise[2] Level, dBA
Suzuki	292 Nomad	292 cc	20	6000	362	750	82
	340 Nomad	336 cc	26	5500	370	850	81.5
	XR-400	395 cc	33	6000	377	950	81.6
	XR-440	432 cc	36	6000	388	1050	81.8
Yamaha	SL 292 C	292 cc	20	5500	337	850	81.3
	SL 338D	338 cc	24	5500	363	950	N/A
	SL 433B	433 cc	30	5500	365	1045	79.1
	EL 433B	433 cc	30	5500	400	1195	79
	GP 292B	292 cc	27	6000	337	950	81.6
	GP 338	338 cc	32	6000	358	1095	82
	GP 433B	433 cc	30	5500	365	1250	81.7
	GP 643 B	643 cc	50	6000	425	1495	82
	SW 433C	433 cc	30	5500	392	1195	79.4
	EW 433C	433 cc	30	5500	431	1295	79.3
	EW 643B	643 cc	42	5500	462	1595	81.9

[1]Reprinted from Invitation to Snowmobiling Magazine, October - November 1972 with permission from Ms Sally Wimer. Noise data from New York State Office of Parks and Recreation.

[2]Noise levels measured in accordance with SAE Recommended Practice J192.

[3]FA denotes Free Air.

APPENDIX C

SAE Recommended Practice for Exterior Sound Level for Snowmobiles

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. • TWO PENNSYLVANIA PLAZA • NEW YORK, NEW YORK 10001

LAND SEA AIR SPACE

TECHNICAL REPORT J192

EXTERIOR SOUND LEVEL FOR SNOWMOBILES—SAE J192

SAE Recommended Practice

Report of Vehicle Sound Level Committee approved September 1970.

1. Introduction—This SAE Recommended Practice establishes the maximum exterior sound level for snowmobiles and describes the test procedure, environment, and instrumentation for determining this sound level.

2. Sound Level Limit—The sound level produced by a new snowmobile shall not exceed 82 dB on an A-weighted network at 50 ft when measured in accordance with the procedure described herein. (See paragraph 6.2 for field measurements.)

3. Instrumentation—The following instrumentation shall be used, where applicable, for the measurement required:

3.1 A sound level meter which meets the requirements of International Electrotechnical Commission Publication 179, Precision Sound Level Meters, and ANSI S1.4–1961, General Purpose Sound Level Meters.

3.1.1 As an alternative to making direct measurements using a sound level meter, a microphone or sound level meter may be used with a magnetic tape recorder and/or a graphic level recorder or indicating meter providing the system meets the requirements of SAE J184.

3.2 A sound level calibrator (see paragraph 6.5).

3.3 A calibrated engine-speed tachometer (see paragraph 5.1.1).

4. Test Site

4.1 A suitable test site is a level open space free of large reflecting surfaces such as parked vehicles, signboards, buildings, or hillsides located within 100 ft of either the vehicle path or the microphone. See Fig. 1.

4.2 The microphone shall be located 50 ft from the centerline of the vehicle path and 4 ft above the ground plane. The normal to the vehicle path from the microphone shall establish the microphone point on the vehicle path.

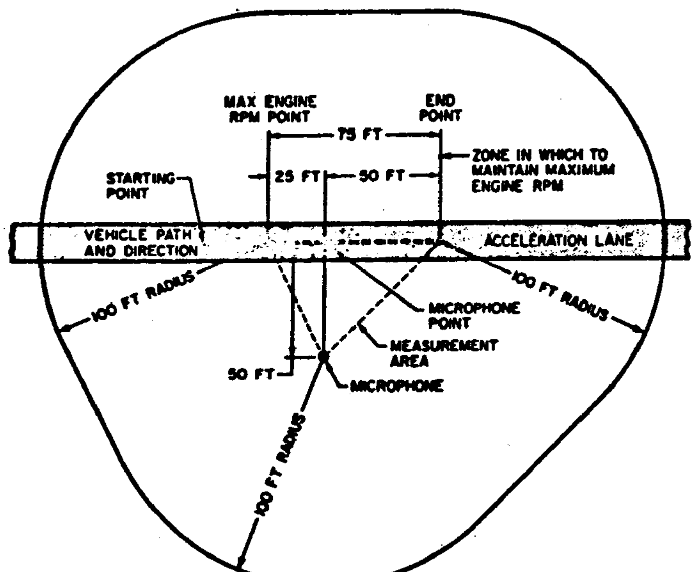

FIG. 1—MINIMUM UNIDIRECTIONAL TEST SITE (SEE PARAGRAPH 4.1)

4.3 A starting point shall be established on the vehicle path (see paragraph 5.1.1).

4.4 An end point shall be established on the vehicle path 50 ft beyond the microphone point.

4.5 The measurement area shall be the triangular area formed by the maximum engine rpm point (see paragraph 5.1.1), the end point, and the microphone location. During measurement, the surface of the ground within the measurement area, including the vehicle path, shall be covered with vegetation not exceeding 3 in. in height.

4.6 The reference point on the vehicle, to indicate when the vehicle is at any of the points on the vehicle path, shall be the front of the vehicle.

4.7 Because bystanders may have an appreciable influence on meter response when they are in the vicinity of the vehicle or microphone, not more than one person, other than the observer reading the meter and the test driver, shall be within 50 ft of the vehicle path or microphone, and that person shall be directly behind the observer reading the meter, on a line through the microphone and the observer.

4.8 The ambient sound level (including wind effects) coming from sources other than the vehicle being measured shall be at least 10 dBA lower than the level of the tested vehicle.

5. Procedure

5.1 Vehicle Operation—Full throttle acceleration test as specified below is the basis for establishing maximum noise capability of the snowmobile. A starting point and maximum engine speed point must be determined for use during measurements.

5.1.1 The starting point for the vehicle is established by carrying out a reverse direction procedure as follows: From a standing start at the microphone point rapidly establish wide-open throttle and allow the vehicle to accelerate until maximum engine speed is reached. The starting point is then 25 ft beyond this point.

5.1.2 For the test, accelerate the vehicle from a standing start by rapidly establishing wide-open throttle at the starting point. Maintain wide-open throttle until the end point is reached.

5.2 Measurements

5.2.1 The meter shall be set for "fast" response and the A-weighted network.

5.2.2 The meter shall be observed while the vehicle is in motion between the starting point and the end point. The applicable reading shall be the highest sound level indicated for the run, ignoring unrelated peaks due to extraneous ambient noises. At least four measurements shall be made for each side of the vehicle. All values shall be recorded.

5.2.3 Observations shall be repeated until the number of readings equals or exceeds the range in decibels of the A-weighted sound levels obtained. The sound level for each side of the vehicle shall be the average of all such readings. The sound level reported shall be that for the side of the vehicle with the highest readings.

6. General Comments

6.1 It is essential that technically qualified personnel select equipment and that tests be conducted only by persons trained in the current techniques of sound measurement. The operation of recording and measuring equipment is likely to be affected by low temperatures. Where measurements are undertaken at temperatures below −10 C (15 F), special precautions must be taken to ensure the reliability of sound level meter readings and/or records.

6.2 An additional 2 dB allowance over the sound level limit is recommended to provide for variations in test site, temperature gradients, wind velocity gradients, test equipment, and inherent differences in nominally identical vehicles.

6.3 Instrument manufacturer's specifications for orientation of the microphone relative to the source of sound and the location of the observer relative to the meter should be adhered to.

6.4 Measurements shall be made only when wind velocity is below 12 mph.

6.5 Instrument manufacturer's recommended calibration practice of the instruments should be made at appropriate times. Field calibration should be made immediately before and after each complete test. Either an external calibrator or internal calibration means is acceptable for field use, provided that external calibration is accomplished immediately before and after field use. An acoustical coupler type of calibrator is recommended for field calibration in low temperature conditions.

7. *Reference Material*—Suggested reference material is as follows:

7.1 ANSI S1.1—1960, Acoustical Terminology.

7.2 ANSI S1.4—1961, General Purpose Sound Level Meters.

7.3 1962 Physical Measurement of Sound.

7.4 International Electrotechnical Commission Publication 179, Precision Sound Level Meters (available from ANSI).

Applications for copies of these documents should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, New York 10018.

APPENDIX D

State Snowmobile Noise Legislation: 1972[1]

State	Effective Date (for machines made after)	Sound Level (dBA)	Distance from Source (feet)
	Sound Level Requirements		
Colorado	1-1-71	86	50
	1-1-73	84	50
Connecticut	1-1-75	85	50
Iowa	7-1-72	86	50
	7-1-73	82	50
Massachusetts	7-1-72	82	50
	7-1-74	73	50
Michigan	Present	86	50
	2-1-72	82	50
Minnesota	6-70	86	50
	2-72	82	50
Montana	6-30-72	85	15
New Hampshire	7-1-73	82	50
	7-1-78	73	50
	7-1-83	70	50
New Mexico	7-1-72	86	50
New York	6-72	82	50
	6-75	78	50
	6-78	73	50
Ohio	1-1-73	82	Not Specified
Oregon	1-4-73	82	100
Rhode Island	6-1-72	82	50
	6-1-74	73	50
Utah	9-20-71	82	50
Vermont	9-1-72	82	50
Washington	1-4-73	82	100
Wisconsin	7-1-72	82	50
	6-75	78	50

[1] Compiled by International Snowmobile Industry Assoc. and reprinted with permission of Sound and Vibration. The original list as it appeared in the May '73 issue has been corrected to reflect the recent change in the New York State law.

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	6.
7. Author(s) Bruce A. Davy, Ben H. Sharp	8. Performing Organization Rept. No.
9. Performing Organization Name and Address Wyle Laboratories	10. Project/Task/Work Unit No.
	11. Contract/Grant No. 68-01-1537
12. Sponsoring Organization Name and Address Environmental Protection Agency Office of Noise Abatement and Control Crystal Mall #2, 1921 Jefferson Davis Highway Arlington, Virginia 20460	13. Type of Report & Period Covered Final (Vol. 1)
	14.

15. Supplementary Notes

16. Abstracts

This document contains information useful for the development of noise emission standards for snowmobiles. Topics covered include information on snowmobile construction, noise characteristics of models currently on the market, and noise reduction techniques and costs necessary to achieve specified noise levels.

17. Key Words and Document Analysis. 17a. Descriptors

Recreational vehicle noise
Recreational vehicle noise control
Snowmobile noise
Snowmobile noise control
Costs of noise reduction

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement Limited supply available at ONAC Arlington, Virginia 20460 Available at NTIS	19. Security Class (This Report) UNCLASSIFIED X	21. No. of Pages
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