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EPA Supplemental Draft Regulatory Impact Analysis

Phase 2 SNPRM: Emission Standards for New Nonroad Handheld Spark-Ignition Engines At or Below 19 Kilowatts

SUPPLEMENTAL DRAFT REGULATORY IMPACT ANALYSIS

Phase 2 SNPRM: Emission Standards for New Nonroad Handheld Spark-Ignition Engines At or Below 19 Kilowatts

June 1999

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ACKNOWLEDGMENTS

PHASE 2

EPA reviewed the technical feasibility for this rulemaking in light of actions with the industry and the California ARB in March 1998. The emission standards for small spark ignition engines set by California ARB's were reviewed by EPA. EPA followed up with discussions with the major engine manufacturers as to the feasibility of adopting standards requiring more advanced emission reduction technologies for Classes III, IV and V engines, than originally proposed in the NPRM. EPA understood that tighter standards could necessitate longer lead times and those have been incorporated in this SNPRM. One benefit of incorporating more stringent standards for handheld engines in this SNPRM rather than several years from now is that the engine manufacturers would have stability for a number of years and also would put their efforts into the long run technologies rather than in the short term, thereby maximizing the use of capital funds spent for emission reduction technologies. EPA acknowledges the hard work, now and in the future, that the engine and equipment manufacturers will undertake in order to assure their part of providing clean air.

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Chapter 1: Introduction

This Supplemental Draft Regulatory Impact Analysis ("Supplemental RIA") contains the supporting information and analysis for this Phase 2 SNPRM for handheld engines and for Class I-A and I-B nonhandheld engines. The information was gathered from sources including the Regulatory Negotiation (1993-1996), industry meetings (1993-1999), EPA contracts, comments to the January 1998 NPRM and discussions with manufacturers and inventors. The Regulatory Negotiation task groups provided information on test procedure, technologies, compliance programs and costs. Industry provided data on the in-use deterioration characteristics of Phase 1engines from their own test programs and on costs of technologies to the consumer. EPA contracts provided information on available technologies, costs of technology changes and regulatory impacts for small entities. Comments to the NPRM provided information on a number of issues including the timeframe for certain technologies, costs of technologies, costs of testing, the need for additional nonhandheld classes, etc. Discussions with manufacturers and inventors since the publication of the NPRM provided EPA with the latest information on emission reduction technologies and costs. All of this information is utilized in the chapters of this Supplemental RIA as described. EPA requests comments on the assumptions, data, and analyses contained in this document. EPA plans to address such comments in developing the final Phase 2 regulations for handheld engines.

Chapter 2 contains a summary of the work done by the Test Procedure

Task Group of the Regulatory Negotiation Committee, as it relates to this proposal, as well as the test procedure changes for this proposal. The work by the Task Group included an investigation into the differences in emission results when small engines[1] are tested on steady state and transient test cycles. The outcome for this proposal is the use of the Phase 1 steady state test procedure with the adjustment in the weightings for the handheld test procedure changed from 90/10 to 85/15 for Mode 1 and Mode 11 respectively.

Chapter 3 of this Supplemental RIA presents the supporting rationale for the level of the standards for this proposal including a comparison of cost estimates for various technologies. Research on technologies for handheld engines has focused on information obtained since Phase 1 was in the process of being finalized. Preliminary work was completed by several sources including the Technology Subgroup of the Regulatory Negotiation and an EPA work assignment with SwRI in 1996[2]. The Technology Subgroup of the Regulatory Negotiation investigated a number of engine emission reducing technologies for the exhaust system and fuel system of small SI engines. The results of the testing during these years revealed that some technologies required other engine improvements to be achieved prior to their use (such as catalysts), some technologies were currently too expensive compared to the price of the engine (such as traditional fuel injection on a handheld engine) and some were in the pre-prototype stages and required additional development before the prototype stage (such as an accelerator pump on a chainsaw engine). Standards being

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[1] The small engines were tested in Phase 1 and “future technology” configurations.

[2] The work assignment with SwRI focused on investigation of currently produced Phase 1 engines and identified the features of low and high emitting handheld and nonhandheld engines.

discussed were 30% below the respective Phase 1 standards for each class (210, 172,116 for Classes III, IV and V respectively).

Most recent discussions with manufacturers, in 1998 and 1999, revealed potential technologies for meeting California Air Resources Board (ARB) standards (54 g/hp-hr (72 g/kW-hr)) for small spark ignition in the engines, 0-65cc. Technologies include mini 4-stroke engines, which were being designed by additional manufacturers and existing designs were being improved, stratified scavenged and compression wave technologies, as well as internal engine improvements with a catalyst. These technologies form the base of the technologies to meet EPA's proposed standards of 50 g/kW-hr for Classes III and IV and 72 g/kW-hr for Class V. For Classes III and IV, EPA assumes the technologies of mini 4-stroke and stratified scavenged and compression wave technologies with a low efficiency catalyst. For Class V, EPA assumes stratified scavenged and compression wave technologies (without catalyst). The use of the technology of internal engine improvement 2-stroke with a catalyst is assumed to be limited for the technology will require more development in order to reach the proposed standards. However, it may be utilized to lower the emissions of specific engine families and then less credits are necessary to allow the manufacturer to comply with the standards.

This Supplemental RIA also includes information on technologies and related standards for Classes IA and IB. Information was collected in discussions with manufacturers since the publish of the January NPRM and a comparison of potential standards was made with the program adopted by the California ARB. In the California ARB program, the engines under 65cc have a unique standard compared to those over 65cc. No distinction is made between handheld and nonhandheld engines in the ARB program as had been done in earlier standards. Given the market structure of the small engine industry, EPA is of the opinion that a harmonized approach, with Class I-A, as allowed in our rulemaking structure, would benefit all. Class I-B serves to allow the smaller Class I engines a higher standard due to the difficulty of smaller engines to meet the Phase 2 standard.

Chapter 4, and Appendix B, contain the data and analysis behind the estimated costs for the technologies for this proposal. Cost information for handheld technologies was submitted to EPA by industry groups and individual companies and through a work assignment with ICF, Incorporated (Docket A-96-55, Item IV-A-01). Information on costs was pulled from each source and updated through discussions with industry after the NPRM was published in order to best represent the likely costs that could be incurred as a result of the new standards being proposed for this industry.

The impact of technology changes to the Phase 1 engine families are based on review of the Phase 1 certification database and the proposed regulatory programs for handheld engine manufacturers. The number of handheld engine families that are likely to be improved are estimated based on the use of ABT by the engine manufacturers[3] and the comparison of their deteriorated[4] Phase 1 emission rates to the Phase 2 standard with a 10% compliance margin[5].

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[3] The ABT calculation is performed for each engine manufacturer and it is based on information in the Phase 1 certification database (engine families, emission data and production estimates.

[4] Deterioration rates and functions are obtained from industry supplied data for both nonhandheld and handheld industries.

[5] This analysis assumes that manufacturers will claim FELs that are 10% below the standard. This assumption is made based on the conclusion that, as manufacturers develop and implement low emitting technologies, manufacturers will want to take advantage of credits to be gained by achieving FELs slightly below the standard in order to offset credit needs by smaller engine families. A larger

Technology improvements for handheld engines include mini four stroke, enleanment and catalyst and compression wave technologies. Costs assumed for each technology are also presented in this chapter. Costs for Class I-A standards are minimal as Class I-A allows handheld engines to be used in nonhandheld applications. Therefore the technology costs are contributed toward the handheld rulemaking. Class I-B costs are minimal for the standard allows existing engines to meet the standards without modification. The only costs are those that are attributed to certification and other related applicable costs which are the same as those for other engine families.

Chapter 5 contains the detail of the compliance program and outlines the costs assumed. The program for this proposal includes certification and production line testing. One major assumption made here for the program is the useful lives that would be chosen by engine manufacturers for their engine families. This was done based on the market focus of the engine manufacturers from low cost consumer to medium quality to high use professional. Appendix C contains the spreadsheets for this analysis.

Chapter 6 contains a description of the methodology used to calculate anticipated emission reductions and fuel savings as a result of this proposal. Appendix F contains related data used in EPA's NONROAD Model. The new engine HC, NOx, and CO emission rates for the Phase 1 baseline were based on the Phase 1 HC, NOx, and CO standards and in-use deterioration characteristics were based on information provided in EPA's Phase 1 model[6]. Phase 2 new

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percentage is not used due to the stringency of the standard in relation to available technologies to meet emission levels much below the standard.

[6] EPA used the NONROAD model for this rulemaking and therefore incorporated the methodology in that model. The in-use deterioration rates provided by some industry members, based on accelerated aging, were not used in place of some

engine HC, NOx and CO emission rates were based on the Phase 2 standards and anticipated HC/NOx split based on anticipated emission reduction technologies. The new engine values were back calculated using the deterioration factors of the assumed technologies. The Phase 2 deterioration factors used in the NONROAD model were the same as those used for the Phase 1 baseline in the model. Brake specific fuel consumption rates were based on those used for the Phase 1 rulemaking and limited additional data.

Chapter 7 contains the aggregate cost analysis for this rulemaking and Appendix E contains the corresponding spreadsheets. The cost estimates presented in Chapters 4 and 5 are used to calculate these costs which include uniform annualized costs for variable and fixed costs per class, average cost per engine per class and overall cost effectiveness. The cost effectiveness with fuel savings is also presented.

Chapter 8 outlines the analysis of impacts on small entities for this proposed rulemaking. The work for this analysis was completed through a work assignment with ICF, Incorporated in 1997 and additional work by EPA in 1999. Through this work, EPA analyzed the expected impact on small production volume engine and equipment manufacturers based on the standards and programmatic content of this proposal[7]. Based on the stringency of the standards, phase-in, ABT and a number of compliance flexibilities, it is anticipated that the impact on small volume manufacturers and small volume models will be minimal.

Chapter 9 contains the background information and analysis on certification useful lives and regulatory flexibility parameters. The standards in

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deterioration estimates in the EPA Phase 1 model. In most cases they are similar.

[7] This includes certification and production line testing.

this proposal would be met by engines based on the emissions at the end of the certification useful life of the engine. Three choices of certification useful lives for handheld (50, 125 and 300) are included in this proposal. These options were based on useful life information by PPEMA and EPA’s own analysis. The options for Class I-A are the same as that for handheld engines. The options for Class I-B are the same as nonhandheld engines which are 125, 250, 500 hours. The production volume cutoffs for the various flexibilities for this rulemaking were based on the information available in the 1996 PSR OELINK database and EPA’s Phase 1 certification database as of September 1998. Chapter 9 contains the rationale behind the decisions for each flexibility cutoff.

Chapter 2: Exhaust Emission Test Cycle and Test Procedures

2.1 Introduction

In order for EPA to successfully regulate exhaust emissions from small nonroad engines, the Agency strives to establish test procedures and cycles which ensure technologies used by manufacturers not only meet the emission standards when tested over the required test procedures, but also result in a predictable emission reduction in actual use. Test procedures are specified to a level of detail necessary to produce accurate, repeatable results. The following discussion is for those engine families using the handheld cycle (handheld engines and Class I-A). Discussion on the test cycle for Class I-B (nonhandheld cycles) can be found in the Phase 1 FRM RIA (Ref 1).

2.2 Phase 1 test procedures and test cycle

The Phase 1 test procedure is described in 40 CFR Part 90, Subparts D and E. The Phase 1 test procedure is based upon well established and accepted on-highway exhaust emission methods and equipment, with some modification to take into account the unique nature of small SI engines. The procedures are designed to accurately measure engine emission performance. A description of the Phase 1 test cycle and procedure can be found in the final RIA for the Phase 1 rule.(Ref. 1) The Phase 1 test cycle is comprised of a series of steady state ‘modes’. A mode is a specified engine speed and load condition, during which the engine is stabilized and emissions are sampled. The emission results for all of the modes are combined using ‘weighting factors’ into a single number for each pollutant.

One distinct cycle (set of modes) is used for small handheld engines. The test cycle for handheld applications consist of 2 modes, one full load condition at rated speed and one no-load condition at idle speed.

The Agency determined during the Phase 1 rulemaking, based on the information available at the time, that for the range of technologies expected to be used to meet the Phase 1 standards, that the Phase 1 test cycle and weighting factors were appropriate.

2.3 Agency review of the Handheld Engine Test Cycle

Prior to proposing Phase 2 emission standards for small nonroad engines, the Agency first undertook, with the cooperation of the engine industry and members of the Negotiated Rulemaking Committee, a test program to determine if the Phase 2 rule should contain a change in the test cycle. The Agency has found for other mobile source categories that steady-state test cycles often do not result in real in-use emission reductions and that ‘transient’ test cycles which more closely mimic real world operating conditions are necessary. A transient cycle means a combination of speed and/or load conditions which vary with time, such as the on-highway Federal Test Procedure for light-duty vehicles or heavy duty engines.

During the Reg/Neg process the Agency expressed concerns regarding the ability of the Phase 1 steady-state test cycles to adequately predict in-use emission reductions for a Phase 2 rule which would result in different engine technologies being employed. The Reg / Neg committee established a Test Procedure Task Group to examine the existing Phase 1 test cycle and procedure and make recommendations to the committee regarding any appropriate changes. (Ref. 2)

The Test Procedure Task Group established by the Reg / Neg committee examined the Phase 1 handheld test cycle and it's viability as a Phase 2 test cycle. The work performed by the Handheld Subgroup is well documented in their final report. (Ref. 3)

The Handheld Subgroup chose a Class IV chain saw as the test engine used to evaluate the effect of transient operation on a future technology engine. The chain saw was picked because chain saws have the highest amount of throttle activations from idle to wide open throttle (WOT) (see Ref. 4 to this Chapter), e.g., chain saw use is considered to be the most transient of handheld engine applications. The Class IV chainsaw was tested in a baseline configuration and with a modified carburetor which included a leaner calibration and an accelerator pump to simulate a 'future technology' engine. The Handheld Subgroup used in-field engine operating data to determine the appropriate weighting between wide-open throttle (WOT, e.g., maximum load) and idle conditions. For chain saws, use was 70 percent WOT, and 30 percent idle. The Handheld Subgroup chose as a representative set of transient test cycles for chain saw operation three cycles. Of the three transient cycles, the Handheld Subgroup determined the "20 second" cycle to be the most appropriate for chain saw applications. The 20 second cycle fluctuated between WOT and idle at a rate of 14 seconds WOT followed by 6 seconds of idle which was repeated for a total cycle time of 360 seconds, or 18 repetitions of the WOT / idle change. The steady-state comparison cycle was a two mode test identical to the

Phase 1 handheld engine test cycle, but with weighting factors adjusted to match the specific operating conditions of chain saws, 0.7 for the maximum power mode, and 0.3 for the idle mode. Table 2-01 contains a summary of the relevant emission test results collected by the Handheld Subgroup.

Table 2-01
Summary of Results from Handheld Transient/Steady State Cycle Program

Test Engine	Cycle	Avg. HC (g/kW-hr)	Avg. NOx (g/kW-hr)	Avg. CO (g/kW-hr)
Class IV Chain Saw w/ Accelerator Pump	Steady-State	113	2.35	99
Class IV Chain Saw w/ Accelerator Pump	20 -Second Transient	113	1.96	109
Class IV Chain Saw w/ No Accelerator Pump	Steady-State	111	2.20	109
Class IV Chain Saw w/ No Accelerator Pump	20-Second Transient	120	2.20	89

Table 2-01 indicates that, if manufacturers choose to adopt a technology similar to that of a lean carburetor calibration, or with lean carburetor calibrations combined with an accelerator pump[8], a transient test cycle is not necessary to predict emission results at this level of control. Anticipated technologies for meeting Phase 2 emission standards (50 g/kW-hr) include a mini-four stroke engine (similar to nonhandheld engine designs which also

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[8] The emission results for this experimental test engine are above the proposed Phase 2 Class IV HC+NOx level of 50 g/kW-hr. This is due to the fact that this was the best technology option at the time to evaluate emission results from transient/steady state tests cycles.

concluded the steady state test cycle was acceptable) or reduced scavenged engine (through internal redesigns) with a catalyst. These technologies will likely not incorporate an accelerator pump as tested above and therefore the test engine comparison may be considered worst case. Therefore, the Agency is proposing to use the Phase 1 two-mode steady state test procedure for Phase 2 handheld engines.

In addition to examining the possible need for a transient test cycle for a Phase 2 program, the Test Procedure Task Group also examined the appropriateness of weighting factors for the two-mode steady state cycle. The Phase 1 test procedure specifies a weighting factor of 0.90 for Mode 1 (maximum power mode) and 0.10 for Mode 2 (idle mode). The analysis and recommendation of the industry group which studied the weighting factor issue is well documented in their final report.(Ref. 4) A group of handheld engine manufacturers collected field cycle data on several handheld applications: 12 trimmers/brush cutter, 4 chain saws, and 6 blowers. The industry group proposed a methodology to determine the appropriate handheld test cycle weighting factors which determined the average WOT/idle time percentages for each application (trimmers/brush cutters, chain saws, and blowers), and weighted these by the HC emissions inventory impact from each application. The HC emissions inventory impact of each application was determined by the following formula:

$$\text{Emissions Inventory Impact} = (TU \times HU \times LF \times HP \times EM) \div TE$$

where, TU = total units sold per year per application
HU = annual hours of use per application
LF = load factor per application
HP = average rated horsepower per application
EM = engine emission factor (g/HP-hr) per application
TE = total emissions per year for all applications.

The results of the analysis performed by members of the handheld engine industry indicate that the appropriate weighting factors for handheld engines is 0.85 for Mode 1 and 0.15 for Mode 2. The Agency is proposing to modify the weighting factors for Phase 2 engines to reflect the results of the analysis performed by industry. Though these new weighting factors are only slightly different from the 0.90/0.10 values used for Phase 1, the Agency believes the Phase 2 program is an appropriate time to make this minor change. This is based on the fact that the EPA Phase 1 certification database shows that the majority of handheld engine families in Phase 1 already meet the Phase 1 standards with some cushion and therefore the calculation change to 0.85/0.15 would not cause a significant change in the overall emission results, as relate to the standard, and therefore additional technologies would not be required to comply with Phase 1. The Phase 2 proposed standards are much more stringent and the change to 0.85/0.15 would be more influential on standard calculations.

Chapter 2 References

1. "Regulatory Support Document, Control of Air Pollution, Emission Standards for New Nonroad Spark-Ignition Engines at or Below 19 kiloWatts" US EPA, May 1995, EPA Air Docket A-93-25, Docket Item #V-B-03.

2. Handouts and Notes from all Meetings of the Test Procedure Task Group held during the Phase 2 Regulatory Negotiation are available in EPA Air Docket A-93-92.

3. "Final Report - Handheld Subgroup of the Test Procedure Task Group", EPA Air Docket A-93-29, Docket Item II-M-40.

4. "Hand Held Composite Duty Cycle", Dec. 30, 1994, EPA Air Docket A-96-55, Docket Item II-D-18

Chapter 3: Technologies and Standards

3.1 Introduction

Section 213(a)(3) of the Clean Air Act presents statutory criteria that EPA must evaluate in determining standards for nonroad engines and vehicles. The standards must "achieve the greatest degree of emission reduction achievable through the application of technology which the Administrator determines will be available for the engines or vehicles to which such standards apply, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers and to noise, energy, and safety factors associated with the application of such technology." This chapter presents the technical analyses and information that form the basis of EPA's belief that the proposed emission standards are technically achievable accounting for all the above factors. Specific areas of discussion include a basic description of the technologies examined, current status of the technology in the existing market, new and in-use emission performance of each technology, costs of each technology, impact of the engine technology on equipment design and use, and impact of the technology on noise, safety, and energy. Finally, this chapter concludes with a discussion of the proposed standards (handheld, Class I-A and Class I-B) and how these standards meet the statutory criteria.

3.2 Technologies

Section 3.2 contains descriptions of technologies for handheld engines which include four-stroke, improved two stroke with a catalyst, stratified scavenged with and without catalysts, sound wave technologies and a spark ignition technology. Class I-A engines use the same technologies as handheld engines. Class I-B engines use technologies similar to nonhandheld engines and are discussed at the end of this section.

3.2.1 Conversion of Handheld 2-stroke Designs to 4-stroke Designs

3.2.1.1 Description of 2-Stroke and 4-Stroke Technology -- Spark-ignited two-stroke technology has seen widespread use in the small engine market, particularly in handheld equipment applications (approximately 16cc-141cc). Four stroke engines have typically been limited to ground supported applications, such as lawnmowers and garden tractors (approximately 84cc-1395cc). The basic operating principle of the charge scavenged two-stroke engine (traditional two-stroke) is well understood; in two strokes the engine performs the operations of intake, compression, expansion and exhaust, which the 4-stroke engine requires four strokes to accomplish. Two-stroke engines have several advantages over traditional 4-stroke engines for use in handheld equipment: high power-to-weight ratios; multi-positional operation; and lower manufacturing costs. Additional information on the basic operation of 2- and 4-stroke engines is widely available in the literature, including the references listed at the end of this Chapter.(Ref. 1),(Ref. 2)(Ref. 3).

3.2.1.2 Current State of 4-stroke Handheld Engine Technology Development -- In recent years, the four stroke designs have drawn the interest of some handheld manufacturers due to the 4-stroke's lower HC exhaust emissions and better fuel economy than 2-stroke designs. At least three handheld engine/equipment manufacturers, Ryobi, Honda and Robin America, have designed and are manufacturing, or plan to manufacture, Class IV (20cc-50cc) overhead valve 4-stroke powered equipment in the U.S. The major equipment using Class IV 4-stroke engines are trimmers/edgers/cutters, pumps, generator sets and tillers[9]. In 1998, EPA observed the operation of a 4-stroke engine in a chainsaw and believes that this will come to the marketplace in the near future.

The manufacturers of mini four stroke engines have made improvements over the initial "scaling down" of the four stroke engine, by Ryobi in 1994, and have gained ground in the power to weight ratio, multi-positional use and manufacturing cost benefits of two stroke engines. However, the four stroke technology has not yet been demonstrated as able to cover the highest range of two stroke engine sizes, such as a 100cc engines; particular challenges include improving and continuing downsizing to improve power to weight ratios. We are optimistic that miniaturization of 4-stroke technology can proceed directly from the most recent work done to miniaturize the Class IV engine. Particularly interesting are the newer mini 4-stroke engines which are lighter in weight than the initial Ryobi engine design and can handle high speeds as has been shown to EPA in a Class IV 4-stroke chainsaw application. The concern of acceleration in the larger engines may be addressed in the future by engine manufacturers.

3.2.1.3 Exhaust Emission Performance of 4-Stroke Technology -- Prior to the introduction of the Ryobi 4-stroke handheld engine in 1994, no handheld 4-stroke engines existed, therefore, no exhaust emission data on uncontrolled engines is available. Federal 1998 Phase 1 certification data for the Ryobi 4-stroke engine shows the new engine HC+NOx emission rate is 37.6 g/kW-hr. Honda has certified three 4-stroke engines (22cc, 31cc and 49cc) at 31, 34.1 and 15.7 g/kWh respectively for HC+NOx. Given the deterioration rates of OHV

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[9] As indicated by the manufacturers in the Phase 1 certification database as of September 1998.

engines in Class I and II (1.4 for OHV in Classes I and II), EPA estimates that the deterioration of HC+NOx emissions would be larger for mini 4-stroke engines due to the increased mechanical friction in the smaller engines and the surface to volume ratio in the combustion chamber. EPA estimates that deterioration for HC+NOx would be approximately 1.5 at a useful life of 300 hours. Using these estimates for the Ryobi 26.2cc engine the in-use emissions are estimated at 56.4 g/kW-hr at 300 hours. For the Honda engines at 300 hours, the in-use emissions are estimated to range from 23.6 g/kW-hr to 51.2 g/kW-hr for the 49cc and 31cc engines, respectively. These estimated in-use emission results indicate that some four stroke engines may need to incorporate additional engine improvements or the addition of a low efficiency catalyst technology to achieve the proposed Phase 2 emission standards with some compliance margin in production.

3.2.1.4 Costs of 4-stroke Handheld Engine Technology -- The costs of converting handheld 2-stroke to 4-stroke technology was estimated by ICF in their 1996 report (<u>see</u> reference 1 to this Chapter). ICF included as part of their cost analysis a tear down and comparison of a Ryobi 2-stroke engine and the Ryobi 4-stroke handheld engine. ICF estimated costs for two annual production sizes, 90,000 and 400,000 units per year, which they estimated as typical for the handheld industry. Table 3-01 is a summary of the cost information contained in the ICF 1996 report for conversion of handheld 2-stroke engines to 4-stroke.

Table 3-01
Summary of per Engine Cost for Conversion of
Handheld 2-Stroke Technology to 4-Stroke Technology (data from ICF, 1996)

Cost Item	Engine Family Annual Production = 90,000	Engine Family Annual Production = 400,000
Additional Parts Estimate	$8.88	$8.88
Additional Labor + Overhead	$1.05	$1.05
Fixed Costs	$4.09	$1.73
Total	$14.02	$11.66

It should be noted that, while ICF utilized 90,000 and 400,000 as representative engine family productions in their 1996 study, production estimates contained in EPA's 1998 Phase 1 certification database shows that 88 percent of the 201 engine families (Classes III-V) have productions under 67,000 (mean=5,200), only 6.5 percent have productions near 90,000 and only 5.5 percent of the engine families have productions above 190,000. As stated in the report by ICF (ICF, 1996), ICF "anticipate(s) that the small engine manufacturer may make certain decisions to reduce the costs of this conversion, such as purchasing the 4-stroke engines from a larger handheld engine manufacturer. On balance between savings both capital and engineering labor and the need to purchase the engines, the small manufacturers may realize a modest savings over manufacturing the engines themselves." EPA is extending this assumption to small volume engine families produced by larger manufacturers. Therefore, it is assumed that most of the engine manufacturers with smaller engine families will choose another technology due to the cost effectiveness of this option[10].

Overall, for those engine manufacturers who have engine families for which 4-strokes would be cost effective, the high volume estimate in Table 3-01 is considered reasonable, based on comparisons with information shared with EPA from one engine manufacturer who quoted a cost of $10.00 per engine at the manufacturing level (Ref. 4).

3.2.1.5 Impact on Equipment Design from Use of 4-stroke Handheld Engine Technology -- The conversion of 2-stroke to 4-stroke technology may likely have some impact on the design of handheld equipment. Impacts of the new 4-stroke designs include the redesign of the shroud design around the engine, replacement of the fuel/oil tanks and air cleaner as well as lower power to weight ratios in some engine sizes.

The lower power to weight ratios would likely not be noticeable to consumers using applications such as lower power residential string trimmers, brush cutters, edgers, blowers, portable generators, and portable pumps. The Agency has heard from handheld engine manufacturers that for engines in the fractional to approximately 1.5kW range, residential users typically do not use the full power rating of the engines to perform the intended work. Therefore, the Agency believes 4-stroke designs could be competitive from a performance perspective with 2-stroke designs in this power range.

However, in larger displacement, higher power engines, the power-to-weight disadvantage of the 4-stroke engine would become noticeable, and would likely impact the user through fatigue from the added weight of the engine, and potentially limiting the functionality of the equipment. The high powered

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[10] Manufacturers may choose to manufacturer four stroke engines if their engine families have many similar components and total a significant number of sales to make four stroke production cost effective.

commercial chainsaws in the Class V category (displacement >50cc) are typically designed for maximum power per cubic centimeter of displacement. In these categories, the 4-stroke engine would likely present a performance problem for users. Two handheld manufacturers (who is producing or has examined the possibility of 4-stroke engine use) have specifically commented that acceleration of the 4-stroke engine is a concern in larger engines.

One benefit of the traditional four stroke engine design is that the consumers would no longer need to pre-mix fuel with 2-stroke oil. However, consumers would need to maintain crankcase oil levels at an acceptable level, and perform periodic oil changes. In chainsaw applications, consumers would have to be sure to not mix the placement of the bar chain oil and the engine oils for they are not interchangeable and can cause permanent engine damage if misplaced.

3.2.1.6 Impact on Noise, Safety, and Energy of 2-stroke to 4-stroke Conversion -- The Agency expects the conversion of 2-stroke to 4-stroke designs would lower the noise levels from handheld equipment. Two-stroke designs are well known for their relatively high noise levels as compared to 4-stroke engines. A large source of noise from 2-stroke designs comes from pressure pulses generated by the exhaust gas at the exhaust port. These pressure pulses tend to be higher in a 2-stroke design compared to 4-stroke engines because the 2-stroke engine requires the higher cylinder pressure to begin the blow-down process (see Chapter 2 "Engine Fundamentals", Patterson, 1972, ref. 15 to this Chapter).

The Agency would expect no change in the safety for the majority of handheld equipment from the conversion of 2-stroke to 4-stroke designs. As discussed in Section 3.2.1.4, the overall design and use of handheld equipment would not change from the conversion to 4-stroke engines, so no change is expected with regards to safety. In addition, the Ryobi 4-stoke handheld equipment has been available for several years, and the Agency is not aware of any safety problems which have occurred from this equipment which can be attributed to the engine type. One area of potential safety concern is with the increased weight of this 4-stroke engine design and extended user use of the product. However, recent 4-stroke engine designs, for the Class IV trimmer market in which they have been used, have been advertized as being comparable in weight to their two stroke counterparts.

However, most, if not all, handheld 4-stroke engines have not been extended into other applications (such as chainsaws) or Classes (III or V) in the marketplace. The 4-stroke Class IV engines are heavier than "lightweight" Class III engines and the power-to-weight ratio and acceleration of a 4-stroke engine in Class V has been raised as a concern by engine manufacturers that manufacture 4-stroke engines. Both of these areas raise safety concerns that need to be considered in the application of this technology.

The Agency would expect significant improvements in the fuel economy from the conversion of 2-stroke to 4-stroke designs. The loss of fuel from the scavenging process for 2-stroke engines results in poor fuel economy which the 4-stroke design does not experience. Based on a comparison of fuel economy data of Phase 1 technology 2-strokes and the Ryobi 4-stroke engine, the Agency would expect a 6 to 16 percent improvement in fuel economy from the conversion of 2-stroke to 4-stroke designs.

3.2.2 Application of Catalytic Convertors to Handheld Engines

3.2.2.1 Description of Catalyst Technology -- Catalytic convertors are add-on devices used to lower exhaust emissions from engines after they exit the combustion chamber. Typically, a catalyst consists of a ceramic or metallic support (often called the substrate), that is coated with a wash-coat which contains catalytic material (typically a rare-earth element such as platinum, rhodium and/or palladium). The catalytic material initiates a chemical reaction which can, depending on the catalyst material chosen, oxidize hydrocarbons and carbon monoxide, and/or reduce oxides of nitrogen.

Additional information regarding the fundamentals of catalytic convertors, and information specific to catalyst and small engines can be found in "Report - Exhaust Systems Subgroup of the Technology Task Group", a report published by a task group established during the Regulatory Negotiation for Small Engine Phase 2 Rulemaking.(Ref. 5)

3.2.2.2 Current State of Catalyst Technology Development -- Historical data indicate that catalysts have seen limited use on small engines in the U.S. Prior to EPA or California ARB small engine regulations, catalysts were used in limited numbers, on some types of indoor equipment such as indoor propane fueled floor buffers (also called floor burnishers), but no handheld applications utilized catalyst technology.

Today, Husqvarna has certified several engine families using 2-stroke technology with a low efficiency catalyst[11]. These Husqvarna families have been developed for string trimmer/brush cutter applications and are currently being sold in the U.S. and Europe. The catalyst technology on these engines is of a unique flat plate design and does not represent that of the honeycomb design used in automobiles. The catalyst was added to the engine only after emission reduction improvements were made to the engine. Emissions had to be reduced from the engine such that the catalyst conversion efficiency could be sufficient to

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[11] As MECA's comments to the NPRM in March 1998 indicates, "For handheld engines, the types of engine design changes needed to allow a catalyst to achieve 30% to 50% efficiency at the end of the engine's useful life are well illustrated by the design changes made by Husqvarna." The exact conversion efficiency of the Huswqvarna catalyst are not readily known.

reduce emissions notably and also remain below the temperature limit requirements set by the USDA Forest Service, as will be discussed later in this section. The engine went under a number of design changes as is described in MECA’s NPRM comments to the docket(Ref. 6) "First, Husqvarna reduced the crankcase volume which increased crankcase pressure. The increased crankcase pressure, combined with the higher back pressure in the muffler, made it possible to optimize the intake cycle and fuel retention. Second, the carburetor was equipped with adjustment caps to prevent it from being set too rich. Third, the remaining unburned fuel and other gas components were converted by a lightweight catalytic converter (10 grams). The standard metal baffle in the muffler was replaced with a special metal plate treated with a catalytic coating. The converter has low mass which ensures lower heat retention than earlier versions. Finally, the muffler contour was redesigned such that cooling air flow was optimized to minimize surface temperatures." However, based on emissions from this engine, it can be seen that more internal improvements are needed to meet EPA’s proposed Phase 2 standards. A letter from MECA to EPA on October 19, 1998 states that there are an estimated 300,000 Husqvarna catalyst-equipped two-stroke engines in equipment for sale in the US and Europe.

3.2.2.3 Exhaust Emission Performance of Catalysts -- Several sources of information exist on this topic. They include the report entitled "Report - Exhaust Systems Subgroup of the Technology Task Group" (Ref. 10) and data from catalysts used on Husqvarna engines that are sold in the marketplace(Ref. 7).

The Exhaust Systems Subgroup of the Technology Task Group Report contains a summary of new engine data on the HC and NOx reduction potential from the application of traditional honeycomb catalysts to 2- and 4-stroke small engines, see Table 3-02. The majority of these engines were uncontrolled or

Phase 1 technology gasoline engines with a prototype catalyst added on.

Table 3-02
Observations of Emission Changes with Catalysts
(Exhaust Systems Subgroup of the Technology Task Group Report)

Engine Design	HC	Class IV Engine Emission Range for HC (g/kW-hr)*	NOx	Class IV Engine Emission Range for NOx (g/kW-hr)*
4-stroke	40-80% dec	range: 15.7-37.6 avg: 29.6	20-80% dec	range: 0.7-2.7 avg: 1.7
			25-50% inc	
2-stroke	20-80% dec	range: 96.7-235 avg: 181	10-20% dec	range: 0.3-3.1 avg: 0.94
			up to 40% inc	

*Emission data is from EPA's Phase 1 certification database as of September 1998 and not the Exhaust Systems Subgroup Report

Husqvarna is the first manufacturer to show the feasibility of catalyst use on handheld equipment in the US marketplace[12]. Husqvarna has certified several engine families under EPA's Phase 1 program which utilize a low efficiency flat plate catalyst on two-stroke engines. The engine has incorporated at least one internal engine improvement in addition to use of a catalyst. The information in Table 3-03 is from the EPA Phase 1 certification database and is from the rich setting of the carburetor.

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[12] Several catalyst equipped chainsaws are sold in the European marketplace for Europe has no temperature restrictions due to use of the professional equipment in winter weather and conditions that are not representative of those in the US.

Table 3-03
New Husqvarna Phase 1 Certification Engines With Catalysts
Class IV Trimmer/Edgers
(g/kW-hr)

Engine Family	Power	Displacement	HC	CO	NOx
XHVXS.0254EB	0.86kW	24.5cc	181.9	622.3	0.3
XHVXS 0274 EA	0.9kW	25.4cc	183.9	663.1	0.2
XHVXS.0314EA	1.07kW	30.8cc	157.0	551.2	0.2
XHVXS.0364EA	1.31kW	36.3cc	154.5	595.8	0.3

With respect to catalyst deterioration, data from MECA's letter of October 19, 1998 shows one 2-stroke Husqvarna trimmer with a catalytic converter plate with an acoustic muffler after 300 hours, shows HC deterioration factor of 1.40[13] and a CO deterioration factor of 0.936 (Ref 7)[14]. Information on the in-use emission performance of catalyst-equipped small engines is very limited, however followup discussion with the source of the data, indicates that the deterioration factor of 1.40 for HC is likely overestimated due to the comparison of incorrect data for this value. In addition, other engine manufacturers have not claimed such high deterioration. There is likely some deterioration based on the Agency's experience with on-highway catalyst technology has shown that

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[13] At a meeting with John Mooney of Engelhard on Tuesday April 20, 1999, it was noted that the 1.40 deterioration factor for HC was in error and Mr. Mooney is in the process of acquiring the correct deterioration factor which is less than 1.4. Engine manufacturers who have worked with catalysts have indicated that catalysts are more emission durable in-use than that indicated here.

[14] The amount of NOx being emitted from 2-stroke engines is very small, especially compared to HC and CO emissions, and therefore any significant change in NOx does not mean it is a reducing catalyst for there is not enough NOx to convert the amount of HC and CO being claimed from the engine.

catalysts are susceptible to degradation in-use. The in-use performance of catalysts can degrade from several mechanisms, including the physical deterioration of the substrate from mechanical shock, vibration, and extreme temperatures, and the deactivation of the catalyst material from chemical poisoning (such as sulfur). Catalysts on Phase 2 technology engines, such as 4-stroke, stratified scavenged or compression wave technologies, are anticipated to experience less deterioration due to the fact that there is none, or less, unburned fuel and oil flowing through the exhaust pipe, and therefore the catalyst.

Several other engine manufacturers have employed catalysts in applications that are soon to be in the marketplace. Tanaka has combined catalyst technology with major improvements in the internal design of the engine in order to meet California ARB standards (72 g / kW-hr after useful life hours) that begin in January 1, 2000. Discussion of Tanaka's engine is contained in section 3.2.4.2.2. It is likely that other manufacturers may employ internal engine redesign with a medium efficiency catalyst to meet California standards for this may be a cost effective option at this time.

The limiting factor for achieving the maximum conversion efficiency will be the ability of the engine manufacturer to manage the heat generated by the catalyst such that the certain measurement points relating to the application meet the temperature limits set by the USDA Forest Service[15]. Techniques such as pulling cooling air into a passage at the exit of the muffler and adding additional shrouding around the muffler are ways to allow the use of higher efficiency

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[15] As of May 1999 it is known that industry has visited the USFS to discuss with them the applicability of the temperature limits to an engine with a catalyst (it is understood that the limits were set on an engine without a catalyst). The manufacturers are planning to conduct testing to verify if there are any specific concerns of temperatures on engines with catalysts that are not currently covered by the USES requirements.

catalysts.

However, there are limitations to the amount of heat that can be dealt with in handheld applications and this is dependent on size, application, ability to reduce the engine out emissions and ability of the engine to handle additional heat. Relating to size, if the exhaust pollutants, in g/kW-hr, were the same on varying size engines (20-90cc for example), the larger size engines (higher kW) would generate a much higher amount of heat due to the amount of flow from the engine which must be converted by the catalyst. Therefore, in order to reduce the heat from the catalyst, the catalyst's percentage conversion efficiency must be reduced or the amount of unburned HC and CO coming out from the engine needs to be reduced. Relating to application, blowers have much more cooling air available to them than other applications and therefore can handle a higher temperature catalyst. The ability to reduce engine out emissions is the major factor in the percentage efficiency catalyst that can be used on an engine. An engine that is of 4-stroke design or incorporates some form of stratified scavenging and related internal engine improvements, will have lower engine out emissions than Phase 1 engine designs. The catalysts can then achieve higher efficiency conversion for they are converting a reasonable amount of pollutants in the exhaust stream, and thereby the heat produced is manageable.

Lastly, relating to the ability of the engine to handle additional heat, Phase 2 engines will have significantly less fuel cooling (due to enleanment or changes in fuel/oil flow inside the engine) than current Phase 1 designs and therefore will depend more on air cooling. To the extent that the air cooling is designed to pass over the engine fins for engine cooling, it may not be available to pass over the muffler as well. If it is able to pass over both the engine and the muffler, the air will be hotter at the time it reaches the muffler and therefore will be less effective for muffler cooling than if it had not passed over the engine first.

In addition, the engine with a catalyst will be exposed to some heat from the catalyst. This will require extra engine cooling in order to assure the engine will not seize. To EPA's knowledge, manufacturers of low emitting 2-stroke engine designs with enleanment, such as compression wave technology by John Deere or stratified charge by Komatsu Zenoah, have not fully addressed issues relating to application of catalysts to these designs. However it has been indicated by one manufacturer that engine redesign will be necessary to minimize and accommodate the heat that is created by the use of a catalyst. This phenomenon will have to be examined on a per engine family basis.

The standards being proposed by EPA assume that low efficiency catalysts will be used on a portion of the market that cannot achieve the standards with solely the technologies of 4-stroke, sound wave technologies or stratified charge technologies. EPA assumes that the standards cannot be achieved with internal engine redesigns of current engines and catalyst due to the fact that internal engine redesigns alone cannot achieve sufficiently low emissions for a reasonable conversion efficiency catalyst.

3.2.2.4 Costs of Catalysts -- Costs are available from two sources for this proposal and include 1) the ICF 1996 report (<u>see</u> reference 1 to this Chapter - the costs of applying a catalyst to a 2-stroke engine were estimated), and 2) MECA's comments submitted in the response to the January NPRM.

The 1996 ICF report presented costs on application of a catalyst only to 4 stroke engines. The Agency estimates the costs of applying a catalyst to a 4-stroke engine would be similar, particularly for the engineering research and development work. ICF's analysis considered the costs for both a metallic substrate and for a ceramic substrate, with the estimated cost of a metallic substrate being substantially more. Table 3-04 is a summary of the cost information contained in the ICF 1996 report for catalyst and 2-stroke engines.

Table 3-04
Summary of per Engine Cost for Application of a Catalyst
to a Handheld 2-stroke Engine (data from ICF, 1996)

Cost Item	Engine Family Annual Production = 90,000, ceramic substrate	Engine Family Annual Production = 90,000, metallic substrate	Engine Family Annual Production = 400,000, ceramic substrate	Engine Family Annual Production = 400,000, metallic substrate
Catalyst	$4.00	$8.00	$4.00	$8.00
Catalyst Assembly Labor	$0.58	$0.58	$0.58	$0.58
Catalyst Fixed Cost	$1.20	$1.20	$0.30	$0.30
Muffler / Heat Shield Hardware Cost	$0.90	$0.90	$0.90	$0.90
Muffler / Heat Shield Fixed Costs	$0.98	$0.98	$0.24	$0.24
Total	$7.66	$11.66	$6.02	$10.02

MECA provided NPRM comments on the cost of catalysts (EPA Air Docket A-96-55, Docket Item IV-D-13), of several conversion efficiencies, for Class IV. Table 3-05 presents a summary of the data supplied by MECA. MECA states that the costs may decrease over time if catalyst technology is encouraged to develop. MECA's cost estimates do not include a number of costs including other costs of the catalyst system (as shown in Table 3-04), the production steps to install the catalyst, or related components, on the engine.

Table 3-05
Summary of MECA per Engine Cost Estimate for Catalyst of Specific HC+NOx Conversion Efficiency per Class

Units of Production	Class IV 1.0hp 2s cat eff 40%->20%* Engine new 172g/kW-hr	Class IV 1.0hp 2s cat eff 60%->30% Engine new 172g/kW-hr	Class IV/V 1.7hp 2s cat eff 40%->20% Engine new 172g/kW-hr	Class IV/V 1.7hp 2s cat eff 60%->30% Engine new 172g/kW-hr	Class IV 0.85hp 4s cat eff 40%->20% Engine new 54 g/kW-hr
5,000	--	--	$6.28	$6.83	--
10,000	$6.25	$6.33	--	--	$4.72
several million	$4.13	$3.50	$4.03	$3.83	$3.05

*Note: the range of efficiency represents catalyst new and catalyst used

Combining Tables 3-04 (catalyst cost) and 3-05 (installation and other costs), the cost of adding a catalyst to an engine could range from $6.71 (industry wide several million) to $10.49 (one catalyst manufacturer 5,000-10,000 volume)[16] depending on the conversion efficiency of the catalyst, engine out emissions and volume of industry usage.

The costs shown in Tables 3-04 and 3-05 account only for the cost of adding a catalyst to a Phase 1 technology 2-stroke engine, not for internal improvements that are necessary to the engine. Internal engine improvements are necessary in order to lower engine out emissions and increase engine out in-use durability prior to the application of a catalyst. As has been discussed in

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[16] MECA provided the estimate of several million based on the concept that it was an industry-wide market, not engine family specific. The cost estimate for 5,000 and 10,000 is based on engine family annual volume. EPA is assuming that this can also be interpreted to mean that 5,000 or 10,000 is the only volume that the catalyst manufacturer sees from the industry.

Sections 3.2.1.4, and will be discussed in 3.2.5.1.2, internal engine improvements could cost an additional $5 to $12.00+ per engine (based on discussion in 3.2.5), depending on the improvements required and the annual production volume of the engine family. Combining the cost of adding a catalyst with the cost of internal improvements to a Phase 1 technology handheld 2-stroke engine results in a potential increase between $11.71 and $21.49 per engine.

3.2.2.5 Impact on Equipment Design and Use of Catalyst -- The use of catalysts would affect the muffler design and engine cooling design of these fuel and air cooled engines. Mufflers would need redesigns in order to house the convertor, as well as additional heat shielding or other safety shields to protect the engine and the user from excessive muffler skin temperature. In addition, the muffler design may need to be modified in order to provide additional air flow to the exhaust gas stream in order to decrease the exhaust gas temperature. This would consist of an outer skin to the muffler which would make the muffler larger than its current size and therefore require engine shroud redesign.

Extra cooling will likely be required by the engine as well to assure it does not seize due to the use of less fuel cooling and presence of an additional heat source. This may require a larger engine fan and redesigned engine fins which may require expansions in the engine shroud design. The path of air cooling may also need to be designed in the engine shroud.

The addition of a catalyst would also add weight to the engine, however, the added weight would likely be negligible compared to the dry weight of the engine.

3.2.2.6 Catalyst Technology Impact on Noise, Safety, and Energy -- The Agency would expect little impact on engine noise from the application of catalysts to small engines. If any impact on noise did occur, it is likely the catalyst plus a redesigned muffler would act to lower the noise generated by an engine, since the catalyst would absorb and not generate sound.

Engine manufacturers have raised concerns regarding the safety of catalysts on small engines. The principal concerns relate to increases in muffler skin temperature and exhaust gas temperature from the use of a catalyst. Title 36 CFR 261.52 directs the Forest Service to prohibit the operation or use of "any internal or external combustion engine without a spark arresting device properly installed, maintained and in effective working order meeting either :(1) Department of Agriculture, Forest Service Standard 5100-a; or (2) appropriate Society of Automotive Engineers (SAE) recommended practice J335 and J335(a)." SAE J335 contains instructions for determining planes at which to measure exhaust gas and surface temperatures and states recommended performance levels (i.e.: temperatures) which should not be exceeded. In order to continue to meet the requirements of the J335, manufacturers may need to limit the conversion efficiency of the catalyst in order to maintain a comfortable margin of safety below the requirements, and / or redesign the muffler system to enhance the heat shielding of the muffler. Husqvarna has certified three engine families to EPA’s Phase 1 standards which utilize a low efficiency catalyst and continue to meet all applicable USDA Forest Service requirements. As long as similar efficiency catalysts are used to meet the standard, given sufficient engine cooling is available, then it is assumed there will be little if any problems with catalyst feasibility. However, higher conversion efficiencies and increased cooling needs by the engine may raise concerns.

Currently, a portion of the handheld industry is questioning whether the temperature performance levels in SAE J335 are appropriate for an engine with a catalyst and are planning to conduct a test program in 1999. Specific concerns include hot muffler surface temperatures (not a plane surface temperature), currently not specified in the SAE J335, as well as a potential increase in heat in the muffler after an engine (and the muffler's system cooling mechanism) is turned off. Both of these situations may result in an exposed muffler surface to dry grass and create a potential fire hazard. The degree of the hazard may be dependent on the conversion efficiency planned for the catalyst such that additional engine out emission reductions do not need to be achieved.

The addition of a catalyst would have no significant impact on the energy consumption of an engine. Catalysts are add-on devices which would have minimal, if any, impact on the engine's air/fuel ratio or power output, and therefore no change in fuel consumption is anticipated. Other changes to the engine, made in order to reduce emissions to more easily utilize a catalyst, would be credited with fuel consumption savings.

3.2.3 Stratified Scavenging

3.2.3.1 Description of Stratified Scavenging -- The December 1998 edition of Power Equipment Trade stated that the problem with emissions from a 2-stroke is that it "use(s) the incoming fuel charge to scavenge, or expel, exhaust gases from the previous combustion event. Unfortunately, about 30% of the intake charge goes out the exhaust port with the exhaust. ... Reducing these scavenging losses is the key to meeting emissions regulations."

Stratified scavenged engines means that the scavenging is done with something other than the fuel/oil/air charge. The stratified scavenged engine design by Komatsu-Zenoah uses air as the scavenging component. Potential downsides of this approach include lower power. Advantages of this approach include lower fuel consumption and lower engine out emissions.

3.2.3.2 Current State of Technology Development -- Komatsu Zenoah is reported planning to produce low emitting engines that incorporate stratified scavenging. The December 1998 issue of Power Equipment Trade contains an in-depth description of the Komatsu-Zenoah "Air Head" technology. The engine is an industrial engine[17] which has undergone major changes to the crankcase, cylinder and carburetor. Description of the engine technology is as follows:

Reduced scavenging is used to keep the air/fuel mixture from short-circuiting out the exhaust port. "RedMax[18] developed a simple way to stratify the incoming fuel charge with a layer of fresh air. This "air head" creates a barrier between the fuel charge and the exhaust port, and it leans out the air/fuel mixture in the combustion chamber."

1. The engine uses a unique two barrel carburetor by Walbro (special Walbro rotary valve carburetor - key part which resembles standard WY-type carburetors). One meters fuel and air in the usual way and the other the stratification air. Outlet pipes on back of insulator block connect to pre-formed tubes (on cylinder). Tubes carry stratification air to transfer ports.

2. "To prevent scavenging losses, the carburetor's upper barrel sends pure air directly to the transfer ports. Each port sports an alloy cover plate equipped with a nipple for the air hose, a reed valve, and a valve stop."
   -Pure air volume is controlled by the carburetor. "At idle the upper barrel is completely closed. To ensure proper idle stability and acceleration, the upper barrel doesn't open until the throttle barrel is about 5-7 degrees off idle. At wide open throttle, both barrels are wide open."
   -"The transfer ports are a closed port design. The air/fuel charge enters the transfer channel through rectangular ports in the cylinder mounting surface. The reed valve assembly does not affect air/fuel transfer from crankcase to cylinder."

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[17] Crankcase is of the three piece, forged variety and it is supported by a pair of ball bearings. Forged rod has caged needles on both ends. The top end is scalloped to encourage lubrication of piston pin and bearing.

[18] Komatsu Zenoah and Red Max are related companies. RedMax is only a brand name of handheld equipment in North American area which is being sold by Komatsu Zenoah America Inc. All of RedMax equipments are manufactured by Komatsu Zenoah Co. (Japan) and Komatsu Zenoah America Inc. is only a distributor for North American area.

> -"The reed valves open in (toward the cylinder). As the piston travels up, negative crankcase pressure draws the reeds open via the transfer ports. A column of pure air fills up the port (at this point the port's cylinder opening is sealed by the piston skirt)."
>
> -"As the piston comes down, the air/fuel mix is compressed and squished into the air-rich transfer ports. Just before bottom dead center, the exhaust and transfer ports open, the air stratified fuel charge enters the cylinder, and exhaust gases are pushed out. Compared to standard 2 strokes, the transfer openings are quite small. They are aimed back, away from the exhaust port, to assure that exhaust gas, not the transfer charge, is first out the exhaust port."
>
> -"Since the air/fuel mix is preceded by a cushion of pure air, very little fuel is lost out of the exhaust port. RedMax engineers report that Air Head scavenging losses are 9% -- a 38% reduction compared to conventional (Schnurle) scavenging. "
>
> -"Not all of the air goes out the exhaust port. Much of it remains in the combustion chamber where it leans out the air/fuel mixture. To ensure the mixture is rich enough to support combustion, the carb is set richer than usual."

"The resulting air/fuel ratio is still very lean compared to conventional mixtures, and that tends to delay the ignition process and cause incomplete combustion." To counter this potential problem, Red Max did the following

1. Spark plug moved to a straight up, dead center location to maximize combustion dynamics.
2. Timing and spark energy have been altered
3. Higher compression was achieved by reducing crankcase volume
4. Changed combustion chamber geography. Piston is slightly domed to mate with hemispherical combustion chamber and is fitted with two compression rings

No information is available in the article on application of a catalyst to the stratified scavenged engine.

3.2.3.3 Exhaust Emissions Performance and Cost -- Komatsu Zenoah has certified their 25.4cc engine to the California ARB standards at 67 g/kWh for HC+NOx and 186 g/kWh CO. Class III or Class IV engines will need at least a 29 g/kW-hr catalyst, 43% (and more in order to produce the engine with some compliance margin and room for deterioration of the catalyst).

The December 1998 article by Power Equipment Trade states that "Despite its closed ports and higher compression, the Air Head's extra-lean combustion makes it less potent than conventionally scavenged engines." Komatsu Zenoah states that the technology results in a decrease in power of 7%.

The 1998 article states that "Red Max sets the price impact at about 3%."

Estimated costs for the stratified scavenged technology are included in the 1996 Cost Study for Phase 2 Small Engine Emission Regulations (Ref 1.), see Table 3-06. However, the specific Komatsu Zenoah design was not used in the cost estimate for it was not known at the time of the study.

Table 3-06
1996 Cost Study (Ref 1.) Estimates for Stratified Scavenging
(1996$)

Cost Category	Item	Cost (1996$)	Total
Variable Hardware	Throttle Valve	$0.50	$1.58
	Other Fittings	$0.50	
Variable Labor	1 min @ $25/hr + 40% overhead	$0.58	
Fixed Cost	Engineering	$370,000	$535,000
	New Master Dies	$115,000	
	Machine Tool Setup	$50,000	

3.2.3.4 Impact on Equipment Design -- Given the slight power loss, the engine size may need to be increased, depending on the manufacturer's equipment designs and power requirements. Space will also have to be made for the larger dual barrel carburetor. The Air-Head's extra-lean combustion likely requires additional engine cooling than current two stroke engine designs. This can be achieved through additional engine fins and optimally designed thinner and wider engine fins. All of these factors could result in the need for a redesigned engine shroud. The Cost Study (Ref 1) estimates no cost impact on equipment due to use of this technology.

3.2.3.5 Technology Impact on Noise, Safety, and Energy -- There are no known impacts of this technology on the factors of noise or safety . The engine uses less fuel and it is assumed 30% less fuel based on the discussion contained in section 3.2.3.1 of this document.

3.2.4 Piston, Combustion Chamber and/or Crankcase Redesign With a Catalyst

Some technologies have been developed to meet a standard of 54 g/hp-hr (72 g/kW-hr) as required by the California ARB. Improvements in internal two-stroke engine design (transfer ports, piston, combustion chamber, etc.) and the addition of a catalyst will allow low emissions such as these to be achieved on some engine sizes and applications. The amount of emission reduction achievable with this technology package will largely depend on the level of emissions exiting the engine prior to the catalyst. The level to which emissions can be reduced with engine improvements determines the percentage conversion efficiency catalyst that can be used on the engine. The catalyst conversion efficiency is limited by the heat produced, by oxidation of pollutants, such that temperatures in predefined planes are in accordance with the USDA Forest Service temperature requirements and other company specific safety requirements.

3.2.4.1 Description of Technology -- The simply designed two stroke engine has room for improvement when it comes to emission reduction. Internal design changes will improve emissions characteristics. As listed in the Stratified scavenging section on Komatsu Zenoah, changes include the following:

1. Higher compression by reducing crankcase volume
2. Change combustion chamber geography. (Ex: slightly dome the piston to mate with hemispherical combustion chamber and is fit it with two compression rings)
3. Move spark plug to a straight up, dead center location to maximize combustion dynamics.
4. Alter timing and spark energy

Other internal engine improvements include design improvements in the engine transfer ports. The use of a catalyst provides additional emission reduction.

3.2.4.2 Current State of Technology Development --

3.2.4.2.1 Husqvarna E-TECH Engine -- Husqvarna describes the E-TECH engine as an engine which "is equipped with a new type of crankshaft enclosure which gives increased crankcase pressure. Higher crankcase pressure and higher pressure in the exhaust system gives the E-TECH engine unique possibilities for lower emissions and a high level of performance." The E-TECH engine is equipped with a new type of lightweight catalytic converter for handheld products. The entire catalytic converter installation gives a weight increase of only 10 grams. The E-TECH motor reduces hydrocarbon and nitrogen oxide emissions.

3.2.4.2.2 Tanaka Stratified Charge Engine With Catalyst -- An in-depth description of the Tanaka technology has been published in Power Equipment Trade July/August 1998. Excerpts from the article are included below. The article states that "Tanaka’s PureFire technology cuts scavenging losses by changing and better controlling air/fuel transfer from crankcase to combustion chamber."

1. "The air/fuel charge enters the crankcase like any piston ported 2-stroke -- through the cylinder intake port as the piston goes up. As the piston comes down, the air/fuel mixture is compressed as usual. However, instead of squirting up into the combustion chamber via transfer ports, the Pure Fire intake charge is forced through a small port on the bottom of the crankcase." (The transfer channel formed in the crankcase mounting surface, runs from the bottom of the crankcase up into the cylinder mounting surface. The four transfer ports are fed through this plumbing system.)

2. "As it travels through the crankcase channel, the fuel charge absorbs crankcase heat, which improves atomization. Furthermore, the channel's small volume and curved route increase flow speed and cause a centrifugal effect. According to Tanaka this "causes a higher content of the fuel (portion of the mixture) to be delivered into the cylinder during the combustion stroke"."

3. "The now layered intake charge flows under the cylinder and into its four closed transfer ports. They are located so that the more concentrated air/fuel are farthest away from the exhaust port."

4. The U-shaped piston ridge's "open end is aimed toward the exhaust port. When the piston is at bottom-dead-center, the ridge is opposite the four transfer ports. In this position, the bottom of the ridge is about level with the bottom of the exhaust port. The top is about half the height of the port. The ridge doesn't block the port, but it acts like a dike that directs the transfer charge away from it. This setup greatly reduces cross-cylinder flow and exit of unburned air/fuel mix."

5. "As the piston moves up, the ridge traps the intake charge and concentrates it around the spark plug electrode. Remember, the top of the cylinder is mirror image of the piston ridge. The two components mesh to form a concentrated combustion chamber. .. This design allows more complete combustion which results in fewer emissions. Catalytic mufflers can't do the job alone, and they can't survive if the exhaust is too dirty so this is important."

6. Muffler contains catalytic converter and spark arrestor setup is typical.
-Catalyst is cylindrical and it is welded to a square plate which is welded to the inside surface of the muffler
-Catalyst is 1 3/8 in diameter and 1.5 in long contains honeycomb substrate covered with a wash coat of noble metals. Exhaust gas must pass through the honeycomb substrate; the material gets extremely hot. It takes a few minutes of operation to get catalyst up to working temp. The catalytic muffler represents about 40% of Pure Fire's emissions reducing technology. The other 60% takes place in the crankcase and cylinder)

This is a quality engine and the engine contains a connecting rod and three piece crankshaft which are quality forgings. Rod ends float on caged needle bearings and the big end is slotted to improve lubrication. The engine uses a conventional intake system with standard Walbro WYJ rotary valve carburetor.

3.2.4.3 Exhaust Emissions Performance and Cost --

3.2.4.3.1 Husqvarna's E-Tech -- Husqvarna's E-tech engine has achieved compliance with California ARB's 1995 standards, however it has not yet reached levels as proposed in this rulemaking. There are, however, additional internal upgrades that may be made as are identified in the Tanaka and Komatsu Zenoah technologies. It is likely that the application of these additional improvements will reduce emissions from where they are currently.

Husqvarna's EPA Phase 1 certification data contains the information contained in Table 3-03. The table is presented again below as Table 3-07. These emission results are from the rich setting of the engine (note: engines must meet emissions in the full range of the carburetor adjustment and therefore worst case is presented here.)

Table 3-07
New Husqvarna Phase 1 Certification Engines With Catalysts
Class IV Trimmer/Edgers
(g/kW-hr)

Engine Family	Power	Displacement	HC	CO	NOx
XHVXS.0254EB	0.86kW	24.5cc	181.9	622.3	0.3
XHVXS 0274 EA	0.9kW	25.4cc	183.9	663.1	0.2
XHVXS.0314EA	1.07kW	30.8cc	157.0	551.2	0.2
XHVXS.0364EA	1.31kW	36.3cc	154.5	595.8	0.3

Cost information on modifications for the E-tech, and potential future E-tech engine designs, is not available.

3.2.4.3.2 Tanaka Pure Fire -- Tanaka's 40cc 2 stroke engine achieves levels of 45 g/hp-hr (60 g/kW-hr) HC+NOx and 117 g/hp-hr (157 g/kW-hr) CO after 300 hours of in-use as shown by certification to the California ARB standards. The 26cc engine has certified at 41 g/hp-hr (55 g/kW-hr) HC+NOx and 85 g/hp-hr (114 g/kW-hr) CO. Tanaka's grass trimmer/brushcutter equipment retail for $450 - $500. It is not known if this technology has been applied to chainsaws.

Some concerns have been raised by other manufacturers as to the high conversion efficiency likely on the catalyst converters. Tanaka sells engines only in the Classes III and IV and a high conversion catalyst will not perform the same in a Class V engine due to the volume of exhaust flow. EPA currently has incorporated this engine technology in its small engine test program and will analyze the conversion efficiency from the catalyst.

3.2.4.4 Impact on Equipment Design -- Based on the engine/equipment design relationship, there can be a range of equipment design impacts. The equipment must employ measures to assure that the equipment meets the USDA Forest Service requirements and this may mean adding additional shrouding around the muffler to mix air with the exhaust gas before it exits the muffler. Changes in the crankcase may influence the equipment shrouding to the extent that it influences the outer dimensions of the engine.

Tanaka has stated the following: 1) their engine has two ounces more weight, 2) 10% less power (therefore moving toward slightly larger displacements), 3) 5% more cost, 4) this technology may be applicable only to pro-quality equipment for the cost impact would probably be higher for low-cost consumer-quality engines, 5)equipment used weighs 18.5 pounds, 50:1 gas/oil mix ratio.

3.2.4.5 Technology Impact on Noise, Safety and Energy --

3.2.4.5.1 Husqvarna E-Tech -- This engine technology employs a catalyst. Therefore the manufacturer is to assure that the equipment meets the USDA Forest Service temperature requirements for exhaust gas plane and exposed surface plane. The technology will result in less fuel consumption based on the internal improvements made in the engine. As relates to noise, there is likely a slight benefit, due to the presence of the catalyst.

3.2.4.5.2 Tanaka Pure Fire -- As with the Husqvarna E-Tech, the manufacturer is to assure that the equipment meets the USDA Forest Service temperature requirements, especially due to the presence of a catalyst. Tanaka states that the engine achieves a 30% reduction in fuel consumption. As relates to noise, there is likely a slight benefit, due to the presence of the plate catalyst.

3.2.5 Compression Wave Technologies

3.2.5.1 John Deere's LE Technology Engine --

3.2.5.1.1 Description of Technology -- As stated in infomration provided by John Deere (see EPA Air docket A-96-55 Item IV-G-30), "(t)he LE technology relates to a compressed air assisted fuel injection system for internal combustion engines, specifically two-stroke engines. Its primary characteristic is in its low emission performance, namely through almost total elimination of an unburned fuel charge during the scavenging process of the exhaust portion of the two-stroke cycle."

The item continues to state that the two stroke engine containing the LE Technology "retains a conventional piston, crankshaft and crankcase from a standard two-stroke engine." The fuel metering system needs to be designed to perform with the engine's needs, although does not need to provide a high precision timing or spray quality. "The fuel injection system is a compressed air assisted system. The injection system comprises an accumulator. The accumulator...has an inlet connectable to pressure within the crankcase and has an exit at the injection port. The accumulator functions as a collector and temporary storage area for compressed air. In this configuration, the source of the compressed air is air scavenged from the crankcase. The piston compresses the air in the crankcase on the piston's downward stroke. ... the two apertures are both provided in the cylinder, one above the air inlet and one below the air inlet. Both apertures are piston ported. In other words, the piston head is sized and shaped to open and close access through the apertures as the piston head reciprocates up and down the cylinder. The accumulator... is a simple channel between the two apertures. The channel could be partially machined into an exterior surface of the cylinder with a cap then being attached to the cylinder to form and enclose the channel with only the two apertures. Alternatively, the accumulator could be provided in a separate member attached to the cylinder. An exit form the fuel metering system is located in the channel proximate the injection port. .... The injection system has minimal moving parts.... the fuel injection system uses the piston head to open and close its ports. Timing of the opening and closing of the ports will be dependent upon location of the ports along the length of the cylinder."

A detailed description of the working of the technology can be found in item IV-G-30. The main thrust behind the technology is a compression wave, which is essentially an acoustic wave, and thus the wave travels at the speed of sound. "As the reflected compression wave exits the inlet (of the accumulator), it causes the fuel and air in the cylinder to be greatly disturbed, in effect functioning as a shock wave. This helps to atomize the fuel and distribute the fuel better in the air. In addition, the reflected compression wave assists in removing fuel droplets that might be adhering to tips or edges of the inlet by surface adhesion or surface tension. The compression wave shocks the fuel off of the surface and into the cylinder."

3.2.5.1.2 Current State of Technology Development -- The technology is in the later part of the development stage on a 25cc trimmer engine. As of May 1999, EPA understands that the fuel system is still in the process of being fully optimized. However John Deere anticipates successful completion of the technology as it is planned for production on their equipment in California in 2000. Detailed here is the history of the progression of the technology since January 1999.

John Deere presented a preliminary prototype of this technology to the industry on February 3, 1999. The prototype was the basis of the information in item IV-G-30. Several issues were raised that questioned the feasibility of the technology and included lubrication at engine operation other than idle, smooth transitions between all engine operating modes, details of the fuel system and sensitivity of the fuel system to atmospheric temperature and pressure. Many of these questions arose due to the fact that the fuel system was not disclosed at the meeting due to the status of patent application.

EPA then visited John Deere on March 1, 1999 to inquire about these concerns and to see the working prototype. Through conversation and visual operation of the test engine at the meeting, EPA understood that many of the concerns raised by attendees to the meeting have been resolved with advancements in the prototype designs. The engine components are lubricated through limited fuel-oil-air mixture that is brought into the crankcase during regular operation of the engine (the wider the throttle, the more fuel-oil-air mixture). The amount of fuel-oil-air mixture that is brought into the engine crankcase can be application specific[19] and is easily adjustable. With respect to smooth operation, the fuel system setup[20] has been updated and is being further improved to address additional issues. Lastly, it appears that concerns of emission level sensitivity to atmospheric temperature and pressure have been resolved. On March 1,1999, EPA observed operation of the engine prototype on the dynamometer and requested that the operator change the CO range from 1.5% to 3.5% CO. The HC analyzer showed a minimal change in HC emissions (ppm basis). The overall g/kW-hr is likely less affected for the power increased as the engine ran richer and the power decreased as the engine ran leaner. These changes coincided with increases and decreases in engine ppm, respectively.

As stated previously, the major benefit to this technology is that many of

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[19] For example, in a trimmer application, 15% of the fuel needed for engine operation can be brought in this manner and 85% of the fuel can be put into the accumulator tube. A chainsaw which runs for longer times at heavy load is able to monitor a higher amount of fuel-oil-air with some emission penalty. However, professional chainsaws have other internal designs that allow them to meet lower emissions without this technology. Therefore this technology does not need to achieve the same emission reduction (on a g/kW-hr basis) as it does with Class IV engines. If more is needed, then a low conversion efficiency catalyst may also be used assuming there is sufficient cooling available.

[20] The fuel system has since been disclosed as of March 26, 1999 in a letter from John Deere to the industry. John Deere's letter briefly described an update on the delivery fuel system and touched on issues of lubrication and cooling (Docket A-96-55, Item IV-G-32). Engine operation within an application and on the dynamometer was viewed by EPA at EPA's visit on March 1, 1999 to John Deere. The trimmer was run under the conditions of cold start, idle, part load, heavy load and hot start. Operation of the engine, in the application and on the dynamometer, was smooth. As of May 13, 1999 it is understood that fuel system design improvements are still being optimized.

the existing engine designs can be utilized with few alterations. The items that will need to be modified include the heat barrier between the engine and the carburetor (the accumulator is mounted in the existing width), two holes in the engine cylinder for the accumulator, a "stuffer" in one of the holes, and minor modifications to the existing carburetor. Additional cooling will be needed by the engine and this can be achieved by adding more fins (which can be done by decreasing the thickness of the existing fins) and widening the fins. Designs for these fins are already available from existing commercial engine designs. Additional engine improvements may be necessary given specific engine designs and applications.

With respect to engine power, JDCP states, in EPA docket item IV-G-30, that the engine power remains nearly the same as the Phase 1 engine without the technology. "The 25cc engine is rated and certified at .75 bhp for trimmer applications and 0.85bhp for blower applications. Its power range is .60 bhp to .98 bhp for trimmers and .60 bhp to 1.18 bhp for blowers." The engine would be classified as a 50 hour residential engine.[21]

EPA is interested in the optimum emission levels that can be achieved with this technology. Based on recent achievements in catalyst application to two stroke engines, EPA is interested in the application of catalysts to this technology. One manufacturer has raised concerns over the application of a catalyst to an engine with high oxygen content in the exhaust. Since a catalyst has not been optimized for this engine, EPA has undertaken an emission test program in the summer of 1999 to investigate the application of catalysts to several engines including this specific engine technology.

3.2.5.1.3 Exhaust Emissions Performance -- In item IV-G-30, John Deere states that the "(l)ow emission of unburned hydrocarbon and good fuel

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[21] JDCP commercially produces the 25cc engine and it is used in string trimmers and blowers under the Homelite brand

economy render the two-stroke engine equipped with the LE Technology capable of meeting the California Air Resources Board Tier 2 standards for 0-65cc Small Off-Road Engines (72 g/kW- hr for HC+NOx)." Data included in the docket item shows that one preferred 25cc prototype was able to achieve levels of 48.22 g/kW-hr HC+NOx and 216 g/kW-hr CO. The technology was also simply applied to a 70.7cc engine (the engine design was not optimized for the technology and the engine was only run on the dynamometer) and achieved emissions of 40.01 g/kW-hr HC+NOx and 138 g/kW-hr CO.

The emission results stated in the above paragraph were based on a preliminary prototype fuel system design as described in information provided by John Deere (see Docket A-96-55, item IV-G-30). As of May 4, 1999, John Deere Consumer Products has submitted data on an engine which incorporates a new updated fuel system. Emission value results increase to 60.73 g/kW-hr HC+NOx and 332 g/kW-hr CO. This is due to the fact that the updated fuel system puts fuel/air/oil mixture into the engine crankcase when the engine is under load (previous design was lubrication at idle only). However, the setting used for the trimmer will not necessarily be made for all applications. The amount of lubrication will be dependent on the application (for example, a chainsaw may need more lubrication due to speeds and loads) and the amount of fuel/lubrication that is needed to go through the crankcase will result in emission variation.[22]

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[22] In a conversation on March 25, 1999, John Deere stated that if a large portion of fuel is put through the engine crankcase, then emissions will be affected. For example, if all of the fuel/oil/air was put through the crankcase, then the emissions would be similar to that of a Phase 1 engine. The main reason is that the scavenging losses from the crankcase will be greater than the engine with the technology. Class V professional units may need more fuel/oil/air to pass through the crankcase than the trimmer application, however the expected overall emission results or technology feasibility is not yet available for the technology has not yet been applied to a Class V unit. If additional emission reductions are required, then the result of the application of catalysts on these engines will

With regard to emissions durability, as of March 25, 1999, John Deere had discovered a durability issue with carbon buildup in the transfer ports in their trimmer engine due to the use of the technology. John Deere believes that the buildup is formed from combustion gases passing into the transfer ports and the transfer ports not being cooled or cleaned by the new fuel/oil/air mixture that traditionally flows up through the transfer ports. This problem may be specific to the John Deere engine, nevertheless, it was found that the transfer ports were too high and therefore the solution includes lowering the transfer ports such that less, or no, combustion gases pass into the transfer ports. John Deere is continuing to perform durability tests to determine any other issues, and to optimize the solution to the issue that they have discovered, for they have not yet run a significant number of engines .

3.2.5.1.4 Technology Cost -- Cost of the technology is detailed in EPA Air Docket A-96-55, Item # IV-G-30. John Deere states that "(D)evelopment time for these changes is short, while both capital and added part costs are low." The cost of the technology includes 1) alteration to the cylinder block consisting of the addition of two holes at the carburetor position, 2) addition of a "stuffer" into one of the holes, 3) carburetor placer replacement which includes the tube and attachment, and a 4) slightly modified carburetor[23]. The cost for the 25cc engine is estimated, by John Deere, to range from $15.71-$4.54 with the lower cost being the long lasting cost after completion of the first engine[24]. The

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become important.

[23] Additional work on developing the technology has revealed that there may need to be some transport redesign and cooling improvements (fins, etc.)

[24] The costs include Added Variable Manufacturing of $4.50-$8.00 and include the accumulator, modified fuel delivery system, modified cylinder and components and labor. The Engine Development and Capital Costs ($75,000-$300,000) include engineering, technical support, however no costs for production tooling (maybe assuming tooling can be modified during die life cycles). These costs are

licensing fee of the technology was proposed by John Deere in a table which ranged from $7.50 minimum to 5% of the cost of an engine over $300 in volumes of 10,000 (ex: $20 for an unit that costs $400 and is produced in 10,000 units/yr)[25]. So, at a minimum, the John Deere technology alone could cost $12.04 given information in this reference. For Classes III and IV where it is assumed that a catalyst will be used with the John Deere technology, an additional cost is added. The cost is explained in 3.2.2.4. and states that the cost of adding a catalyst to an engine could range from $6.71 (industry wide several million) to $10.49 (one catalyst manufacturer 5,000-10,000 volume)[26] depending on the conversion efficiency of the catalyst, engine out emissions and volume of industry usage. Based on the fact that the standards can be met with two stroke technologies with catalysts, it is expected that the industry volume will be high. Therefore the cost of $6.71 is used for a minimum total of $18.75 (for a minimum licensing fee and production cost of 12.04). The total cost will be higher due to changes in the John Deere licensing fee for various production volume engine families. Class V engines are assumed not to use a catalyst with this technology.

The licensing costs are of a concern to at least several in the industry who have stated the licensing fees are above the profit margin for some consumer marketed equipment. This is of a special concern to competitors with John Deere who will be disadvantaged for John Deere does not have to pay the royalty.

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amortized at 9% over 5 years. The totals are then divided by estimated productions of 500,000 and 10,000 to yield the range.

[25] However, John Deere has stated they are open to other licensing offers.

[26] MECA provided the estimate of several million based on the concept that it was an industry-wide market, not engine family specific. The cost estimate for 5,000 and 10,000 is based on engine family annual volume. EPA is assuming that this can also be interpreted to mean that 5,000 or 10,000 is the only volume that the catalyst manufacturer sees from the industry.

Professional equipment manufacturers have commented about concerns that the price will impose a high added cost on professional equipment.

The cost of the licensing fee with respect to the licensing fees of other engine technologies, such as the Ryobi or Honda 4-stroke, is unknown and therefore EPA has no knowledge of the comparison of the costs being requested by John Deere. It is understood that industry can incorporate additional equipment improvements (easy start, applications the equipment can handle,etc.) to cover costs for emission reduction technologies in the competitive marketplace.

3.2.5.1.5 Impact on Equipment Design -- In regards to impact on equipment design, in Docket Item # IV-G-30, John Deere states that "no modifications are required to the standard piston, crankcase and crankshaft: only small adaptations are needed for the cylinder and fuel metering system (carburetor): and the only additional component is an accumulator, which can be in the form of a simple channel or tube. The LE Technology can thereby be readily applied to existing engines without substantial change to the molds and tooling of existing engine components or housings."

However, based on discussions of other engine designs with several Class V equipment manufacturers, it is clear that the impact on equipment design depends on the manufacturers current product. Manufacturers that tightly house the engine, or have the shroud fill in as part of the engine may not have available room for the accumulator tube and therefore there may be minimal changes to the plastic shrouding surrounding an engine. Additional cooling may also be an issue on engines that have well designed cooling systems, however these issues will likely need to be addressed regardless of which low emitting technology is utilized for the engine is likely enleaned and less fuel/oil is used to cool the engine.

3.2.5.1.6 Technology Impact on Noise, Safety and Energy -- In

Docket Item # IV-G-30, John Deere stated that "No measurements have been made to determine the impact of the LE Technology on the sound characteristics or performance of the two-stroke engine. Observation of the LE engines, without quantification, suggests that there is no appreciable difference in sound levels between the engines and standard engines." John Deere also states that "during the testing of the prototypes, the fuel consumption of both the 25cc and 70.7cc LE engines was measured. A reduction of approximately 30% as compared to conventional or standard engines was demonstrated."

3.2.5.2 Boswell Super Cycler – In 1998, EPA learned of a vaporizing carburetor concept that has been shown to be applicable and effective in improving acceleration and power in two stroke engines. The technology has been used successfully in performance machines such as snowmobiles (which was confirmed)(Ref. 8) and motor cross bikes. As stated in the Boswell brochure, "The Super Cycler works in the last few centimeters of the intake tract to further enhance the production and delivery of super-cooled, completely phase-shifted vapor. The device allows the return pulse to feed its energy into the next intake pulse, adding both completely phase shifted vapor and return pulse energy to each succeeding intake pulse. The high frequency reverse wave energy created by piston reciprocation pounds its way back toward the center of the carburetor along the edges of the manifold and carburetor outlet where it is directed into a narrow outer chamber created by the Super Cycler. This high-velocity pulse then bounces back toward the direction of positive flow and into the rushing positive pulse through a series of holes drilled in the section of the Super Cycler closest to the throttle valve. The Super Cycler utilizes the return pulse as a self-powered mini supercharger, setting up a kind of pulse driven feeding frenzy in the intake manifold that is reponsible in part for the increase in power. The function of the Super Cycler is based on Boswell's discovery that the return pulse is strongest in the boundary layer next to the venturi wall. The return pulse is channeled into the narrow Cycler chamber where it is reflected back through a series of holes creating a reverse pulse-powered velocity booster" (Ref. 9). No detailed information specific to handheld equipment has been received by EPA and therefore no conclusion can be made about its applicability to 2-stroke handheld designs.

3.2.6 Other Technologies

3.2.6.1 Spark Ignition Technologies -- The technology described below is considered a supplemental technology based on the fact that a manufacturer cannot rely on the technology alone to meet the proposed standards. Limited data available to date shows that it may provide a benefit over the useful life of the engine.

3.2.6.1.1 Current State of Technology Development -- During the summer of 1998, Pyrotek presented EPA with information on a spark ignition technology that it had developed(Ref. 10). It is a very simple technology and has shown to yield lower emissions in 2-stroke engines. Versions of the technology are in the marketplace today, however the inventors have investigated those technologies and note that theirs has some benefits that have not yet been included in previous designs.

3.2.6.1.2 Exhaust Emissions Performance -- Pyrotek has performed a number of tests of the technology on 2-stroke and 4-stroke engines. They have seen a notable benefit in new engine values on 2-stroke. The tests have confirmed improved BSFC and it is believed that the absence or reduction of combustion chamber deposits over time would contribute to improved emission deterioration over time. Some durability tests have been performed on 2-stroke engines.

The engines selected for the study were two-stroke Homelite super 2 chainsaw engines (model No. 246Y, air-cooled, single cylinder, piston ported, supplied with a DJ7Y plug 32.4 cubic centimeter displacement). The engines were tested new and the emission levels noted in Table 3-08 were achieved. Refer to the report for testing specifics.

Table 3-08
Engines At New (0 hours)

Parameter	Engine #2 Conventional	Engine #1 Pyrotek	Engine #1 Conventional
Power (kW)	1.03	0.98	0.99
HC (g/kW-hr)	154.0	166.0	165.5
CO (g/kW-hr)	292	268	310
CO2 (g/kW-hr)	936	1010	965
NOx (g/kW-hr)	2.42	2.51	2.00
BSFC (g/kW-hr)	653.4	676.2	691.8
Fuel Flow (g/hr)	673.4	661.5	684.0

After 25 hours of operation the results in Table 3-09 were seen.

Table 3-09
Emission Results After 25 and 50 Hours

Parameter	25 Hours		50 Hours	
	Engine #1 Pyrotek	Engine #2 Conventional	Engine #1 Pyrotek	Engine #2 Conventional
Power (kW)	0.97	0.93	0.97	0.85
HC (g/kW-hr)	135.6	158.40	125.4	178.2
CO (g/kW-hr)	193	260	215	342
CO2 (g/kW-hr)	1096	1030	965	985
NOx (g/kW-hr)	6.29	4.11	2.85	2.35
BSFC (g/kW-hr)	700.9	754.6	750.2	803.6
Fuel Flow (g/hr)	676.5	701.4	726.7	686.4

The report points out that the emissions from the engine with the Pyrotek spark plug has lower emissions by 25% for CO and 14% for HC after 25 hours. The differences in HC and CO in both engines compared to data in 3-04 are partly due to the different ambient humidities for the 0 and 25 hour tests.

The engines were run for another 25 hours (total of 50) and the emissions were measured. It should be noted that the engine with the conventional spark plug had trouble starting and therefore the start procedure was repeated for 10 minutes until it finally started. The engine with the Pyrotek spark plug started without difficulty. Results show the engine with the Pyrotek plug was lower than the engine with the conventional plug by 37% for CO and 29% for HC. The report states that "it is likely that the high level of HC emission of the engine with the conventional spark plug may have been partly caused by the amount of priming used when starting difficulties were experienced."

Upon completion of the test, each engine was dismantled and examined. The report stated that "the engine fitted with the conventional spark plug had a considerable build-up of soot-like deposits in the piston-ring grooves and around the exhaust port. Also, the piston face and combustion chamber walls of t his engine showed many regions of small discoloration/damage on the piston face of the engine with the Pyrotek plug was considerably less and much more uniform. The Pyrotek spark plug exhibited a light brown discoloration of the insulation around the center electrode, while this region of the conventional plug was considerably darker." Photographs of the engine are available in the report.

3.2.6.1.3 Technology Cost -- The report provided no information on cost of the technology, however it is anticipated that it would cost slightly more than the spark plug used today. The cost would likely be heavily influenced by the volume of the order in the industry.

3.2.6.1.4 Impact on Equipment Design -- The spark ignition technology would replace the existing spark plug. Therefore, besides an increase in exhaust and cylinder head temperatures at wide open throttle of approximately 20 degrees C for the Pyrotek spark plug, which additional fins may be able to dissipate, there is no expected impact on the equipment.

3.2.6.1.5 Technology Impact on Noise, Safety and Energy -- No changes are expected based on this spark plug technology.

3.3 Proposed Exhaust HC+NOx Standards for Class III, IV and V Engines

This section contains information the Agency used to determine the appropriate standards contained in the proposed regulations. Additional information is contained in the Preamble for this Rulemaking.

The handheld engine industry is made up of manufacturers that make small engines for a variety of applications and intended users (consumer and commercial). Engine families certified to the Class III standards are used almost solely in trimmers/edgers/cutters and the majority of engines are sold mainly to low use consumers. The engine families certified in Class IV cover a wider range of applications from trimmers/edgers/cutters, generator sets and blowers to chainsaws for use by low use consumer and commercial users. Engine families certified in Class V are mainly used in chainsaws, rammers, and cutoff saws aimed at the commercial users. Very few trimmers and blowers are certified in this class.

The Agency expects the proposed in-use standards can be met through conversion to four stroke (some with minimal conversion efficiency catalyst), stratified scavenged engine with (Class III and IV) and without (Class V) a minimal efficiency catalyst and compression wave technologies with (Class III and IV) and without (Class V) a catalyst. Other supporting technologies include engine redesign plus catalyst and potentially spark ignition technologies. It should be noted, however, that there are currently limitations to the spread of most technologies to all engine sizes covered by this rulemaking.

Limitations for some of the technologies include loss in power, engine technology size and/or technology performance. Technologies in which there have been losses of power from the original engine design include engines that incorporate stratified scavenging or significant engine enleanment without improved fuel delivery. A Class III engine may need to be certified as a Class IV engine due to increase in engine size to yield the same power as the original engine. Four-stroke technology has several issues for engines in the size range of Class V engines. The concerns are over the power/weight ratio as well as the acceleration of the engine, which relates to technology performance. Technology performance also relates to concerns over high efficiency catalysts, especially in Class V engines that have not reduced engine out emissions significantly. The volume of exhaust flow is much larger on larger engines and therefore the ability of a catalyst to convert the same efficiency of pollutant, as on a smaller engine, and still remain cool enough to meet the USDA Forest Service temperature limits, has proven difficult for manufacturers.

The only technology with little anticipated size and application constraints is the compression wave technology. While John Deere has indicated that they see no reason for limitation of use of the technology on all small engines, the technology has not actually been applied to all engine sizes or applications. Engine manufacturers of professional use products in Class V have expressed concerns with the technology on their products. Specific concerns include lubrication in high speed and high load applications, such as chainsaws, and smooth fuel system operation across all modes of equipment use. Based on the most up to date information from John Deere (May 25, 1999), EPA acknowledges that more development fine tuning is required, however EPA is optimistic that manufacturers may likely be able to apply the technology to slightly modified existing two-stroke engines, while achieving significant emission reductions. The addition of a low efficiency catalyst is a possibility due to the low engine out emissions from this engine. However, questions still exist as to the ability of the engine to cool the muffler effectively as well as the engine. EPA assumes that with a low efficiency catalyst that there is sufficient cooling available.

Table 3-10 contains a summary of publicly available emission data from a number of technologies described earlier in this chapter. The in-use HC+NOx values are listed next to the related technology. Some in-use values are estimated and some are from manufacturer data as certified to California ARB standards. A column has been included which estimates emissions if a catalyst is utilized on the engine. With the low engine out emissions achieved by these technologies, a 30g catalyst may be possible. However, given the likely air cooling availability (due to it being rerouted around the engine for engine cooling), a 10-20g catalyst is assumed.

Table 3-10
Technologies and Likely Achievable In-Use HC+NOx Emissions

Technology / Manufacturer	HC+NOx (g/kW-hr)	Methodology for Calculation of in-use emission	Class and Application	Assuming cooling is available, emissions w/ 20g/kW-hr Catalyst for III & IV, w/ 10g/kW-hr Catalyst for V**
Stratified Charge*/ Komatsu-Zenoah	67	California ARB cert data (300 hrs)	Class IV trimmer	47
4-stroke*/Honda	51.2	Phase 1 cert data with assumed 1.5 df	Class IV trimmer	31.2
LE Engine Technology*/ John Deere Consumer Products	66.8	Docket item # IV-G-32 with assumed 1.1 df	Class IV trimmer	46.8
LE Technology/ John Deere on Stihl - very preliminary prototype	36***	Docket item # IV-G-30 with assumed 1.1 df	Class V chainsaw	26***

*Technologies may be limited in applicability to all sizes and applications of handheld engines.
** 20 g catalyst assumed for Class V engine due to exhaust volume/catalyst size concerns
*** These results are from use of preliminary fuel system. On the Class IV trimmer, emission results increased with latest fuel system design and it is expected the same will happen if the fuel system were applied to the Class V engine. Also, issues of application of technology to professional Class V engines, including lubrication, etc. remain unanswered due to no further work on prototype.

Table 3-10 illustrates that low emissions are, and are potentially, feasible on a number of Class IV engines. Class III engines are similar in size to the Class IV engines and a slight increase in size (~2cc) will move all but one of the Class III engine families to Class IV. While power has shown to remain similar to Phase 1 engine levels with the John Deere LE technology, other technologies may likely have a loss in power as the engine is enleaned and therefore the engine size may need to increase slightly. In this document, EPA has assumed the slight increase in engine size is acceptable and therefore the technologies and related standards set for Class IV are assumed applicable to Class III. EPA requests comment on these assumptions

Due to the feasibility of technologies, or very promising technologies, demonstrated by manufacturers in Class IV engines, as shown in Table 3-10, it is believed that low emissions are achievable. Based on information available at the time this document was prepared, EPA believes four stroke technology will be very cost effective for high production engine families and technologies such as the John Deere LE engine or Komatsu Zenoah stratified charge will be relatively cost effective for lower volume engine families. While the engine cooling capabilities of an engine will need to be improved due to less fuel/oil cooling (due to the use of stratified scavenging or reduced scavenging designs), EPA assumes that there is some additional cooling available for the application of a low efficiency catalyst. Therefore, the Agency is proposing an average in-use HC+NOx standard of 50 g/kW-hr for Classes III-IV. These standards would be applicable for the proposed useful life categories of 50, 125 and 300 hours. The Phase 2 standards would phase-in from model year 2002-2006 for Classes III and IV as shown in Table 3-11.

For Class V engines, Table 3-10 shows results for only one engine and it is on a very preliminary prototype from John Deere on a Stihl engine. The EPA is optimistic that the John Deere technology and Komatsu Zenoah technology will be applicable to professional equipment in Class V, although it has not yet been proven. It is understood that there are limitations in the application of 4-stroke technology across all of the size range of Class V engines due to power/weight and acceleration in Class V applications. As with the Class III and IV Phase 2 engines, it is assumed that a low efficiency catalyst can be applied if necessary. Due to the unknowns of applying the John Deere LE and Komatsu Zenoah technologies to Class V engines, a standard of 72 g/kW-hr is being proposed for Class V engines. (72 g/kW-hr is the same as the Phase 2 standard the California

ARB has set for such engines.) The standard would be phased-in from 2004 to 2008 for Class V as shown in Table 3-11.

A standard of 50 g/kW-hr is not being proposed for Class V engines based on the assumption that professional Class V engines may need more cooling than consumer Class IV engines and that if all available cooling is used to assure smooth operation of the engine with the lean technologies, that the ability to cool the muffler to use a catalyst will be limited. Or, if the compression wave or stratified scavenging technologies need to be run richer than on the Class IV engine to provide sufficient lubrication, then possibly a portion of the air cooling can be used to cool a muffler with a catalyst. Several companies that manufacture Class V engines have met with EPA to claim that 87 g/kW-hr is the lowest achievable standard for Phase 2 engines. EPA believes this claim is based on manufacturers' current technology projections and does not take into consideration the application of stratified charge or sonic wave technology to their engines. EPA believes that such technologies can be applied to Class V applications and can achieve emissions at or below the proposed 72 g/kW-hr HC+NOx standard. EPA request comments on these assumptions.

Phase 2 technology 2-stroke engines will result in approximately a 78 percent reduction in the in-use emissions of small spark-ignition handheld engines at or below 19kW.

Table 3-11
Phase-in HC+NOx Standards (g/kW-hr) for Handheld Engines*

Engine Class	Model Year						
	2002	2003	2004	2005	2006	2007	2008+
Class III	226	200	150	100	50	50	50
Class IV	187	168	129	89	50	50	50
Class V	(Ph 1)	(Ph 1)	138	129	110	91	72

* The proposed standards are based on a 30%, 40%, 60%, 80%, 100% phase-in of 50 g/kW-hr standard for Class III and IV, and 72 g/kW-hr for Class V.

Regarding the phase-in leadtime for the standards, some industry members have indicated the proposed standards would require significant proveout time for the technology to their own products. The phase-in period plus the lead time anticipated if this rule is finalized will allow manufacturers 2-8 years to make the necessary changes to existing product lines in order to meet the standards[27]. Flexibilities for small volume engine families and small volume engine manufacturers allow a slightly longer timeframe.

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[27] Small volume engine manufacturers and small volume engine families have until three years after the last date of the phase-in to comply with the Phase 2 standards. This means 2009 for Classes III and IV and 2011 for Class V.

Chapter 3 References

1. "Cost Study for Phase Two Small Engine Emission Regulations", Draft Final Report, ICF Consulting Group and Engine, Fuel, and Emissions Engineering, Inc. Oct. 1996, EPA Air Docket A-96-55, Docket Item # IV-A-01.

2. "The Basic Design of Two-Stroke Engines", Gordan P. Blair, Society of Automotive Engineers, Inc., 1990.

3. "The Internal Combustion Engine in Theory and Practice, Volume 1", C.F. Taylor, The M.I.T. Press, 1985. See Chapter 12, 'The Performance of Unsupercharged Engines'

4. "Comments of Ryobi North America, Inc. and Ryobi Outdoor Products, Inc. on EPA Proposed Phase 2 Emission Standards for small (25hp or less) Handheld Engines", EPA Air Docket A-96-55, Docket Item # IV-D-18.

5. "Exhaust Systems Subgroup of the Technology Task Group - Report", September 25, 1995. Available in EPA Air Docket A-95-55, Docket Item # II-D-17.

6. "WrittenTestimony of the Manufacturers of Emission Controls Association on Proposed Phase 2 Emission Standards for New Nonroad Spark-Ignition Engines at or Below 19 Kilowatts", March 13, 1998, EPA Air Docket A-96-55, Docket Item # IV-D-13.

7. Letter from Bruce Bertelsen of MECA to Bob Larson of the EPA, October 19, 1998, EPA Air Docket A-96-55, Item # IV-G-25.

8. Conversation between Cheryl Caffrey and David Wahl Regarding the Boswell Energy System technology on snowmobiles, December 15, 1998, EPA Air Docket A-96-55, Docket Item # (yet to be assigned).

9. "The Boswell Technology", Boswell Fuel Systems, EPA Air docket A-96-55, Docket Item #IV-D-24.

10. "Technical Summary and Report Spark Ignition Device Research", Pyrotek, Inc., November 13, 1998, EPA Air Docket A-96-55, Docket Item # IV-G-29.

Chapter 4: Technology Market Mix and Cost Estimates for Small SI Engines and Related Equipment

This chapter analyzes the variable costs and fixed costs per engine family modified in each class. This chapter also presents a "schedule" for how these engine modifications would be phased-in. These costs are costs to manufacture.

The Clean Air Act at section 213(a)(3) requires that EPA must consider cost in establishing standards that achieve the greatest degree of emission reduction. This Chapter presents the Agency's estimation of costs for expected technologies including associated variable costs (hardware and production), fixed costs (production and research and development), related equipment costs, engine fuel savings and engine compliance costs. Details of the methodology for determining the compliance costs are presented in Chapter 5.

To calculate estimated costs incurred by engine manufacturers, market mix[28] percentage estimates for pre-Phase 2 (Phase 1) and Phase 2 engines must first be assessed. This is done by determining the Phase 1 engine market mix from estimates provided by manufacturers as part of their 1998 model year certification applications. Analysis of this data formed the assumed product mix that will be in place as a result of the Phase 1 rulemaking. A comparison was then made to the assumed product mix (including technical enhancements) that would need to be in place to meet the Phase 2 standards. A description of the methodologies and resultant market mixes for these estimates are described in section 4.1., Engine Technology Market Mix Estimates.

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[28] Market mix is the percentage of engines of specific engine design sold in the marketplace (ex: 4-stroke and 2-stroke) compared to others in the same Class.

Several of the emission reduction technologies assumed feasible for this rule include changes in manufacturer production, such as changes in the cylinder die designs and the number of tools. The following definitions were utilized to separate costs for emission reduction technologies into variable hardware, variable production, fixed production and fixed research and development. Variable hardware costs are those costs which are associated with pieces of hardware added to an engine. Examples include rocker arms and push rods that are added to an engine that is converted from 2-stroke to 4-stroke OHV. Variable production costs are those costs which relate to inputs in production. These costs consist of additional production tasks, such as assemblers for additional components for a 4 stroke line which were not in place for assembly of a 2-stroke line. Variable hardware and production costs are determined by estimating variable costs for each emission reduction technology and applying those costs to that portion of the Phase 2 product mix assumed to have required that technical change. The methodology for estimating variable hardware and production costs for applying emission control technology are presented in 4.2. Variable Hardware and Production Cost Estimates per Engine Class.

Fixed production costs are those costs which are related to added or modified piece(s) of machinery to an existing engine line due to this final rule, such as tooling and die design changes. Fixed costs of research and development are those costs associated with development of engine and engine component designs to meet emission standards. These costs are incurred prior to production and amortized for recovery over 5 years and therefore do not apply on a per engine basis as do variable cost estimates. Discussion of the methodology utilized to estimate fixed costs are presented in 4.3. Fixed Production and Research and Development Cost Estimates per Engine Class.

Engines are utilized in equipment which may require alterations due to changes in the engines that would be required to meet the Phase 2 proposed standards. A discussion of equipment impacts is presented in 4.4 Equipment Cost Estimates. Lastly, Section 4.5. details fuel savings and changes in power expected with the Phase 2 engine technologies. Cost impacts from changes in maintenance, engine durability and life expectancy were not quantified or included in this cost analysis. These factors are expected to improve the quality of Phase 2 engines in ways which should directly benefit the consumer, but information was insufficient to quantify these benefits.

4.1 Engine Technology Market Mix Estimates

Market mix estimates consist of the number of engine families and sales estimates of engine designs (i.e., 2-stroke, 4-stroke) per class (i.e., Classes III-V). Market mixes are determined for the 1998 model year (to characterize technology under the Phase 1 regulation) and the first year of full implementation of the Phase 2 emissions regulation. The following describes the methodology used to estimate market mix and emission reduction technologies for small SI engines. This analysis includes only those engine families and production volumes certified to EPA's Phase 1 standard as of September 1998. This does not include the production volumes for engine families that are certified for California ARB's standards for those are covered by ARB. A summary of results are in Tables 4-01 to 4-04 with manufacturer specific details and emission data in Appendix B Manufacturer and Product Summary.

4.1.1 Phase 1 Market Mix

The most accurate and up-to-date information source on engine families and manufacturers in the marketplace today is the EPA Phase 1 engine certification list. The list, as of September 1998, was utilized to estimate the number of engine families per engine design and technology for Classes III-V[29] as shown in Table 4-01 (Table B-01 in Appendix B contains breakout per manufacturer) . Table 4-02 summarizes the sales in each engine class per engine design.

Table 4-01
Phase 1 Technology Mix
Engine Families per Technology Type

Engine Class	2-stroke	2-stroke w/cat	Mini 4-stroke	Total
III	9	--	--	9
IV	120	3	4	127
V*	49	--	3	52
Total*	178	3	7	188

* Note: this does not includes engine families for snowblowers and lawnmowers which have their own special provisions. Snowblowers have to meet only the CO standards as outlined in this SNPRM.

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[29] There are special cases in which engines do not have to meet the Phase 1 standards. These include engines utilized solely in wintertime equipment, such as all of snowblowers and ice augers, that only have to meet the CO standard. Two- stroke Class I engines are under a special program to be phased-out over a period of years and need only meet the handheld HC+NOx and CO standards.

Table 4-02
Assumed Phase 1 Sales per Class and Technology Type
(Source: EPA Phase 1 Certification Database as of September 1, 1998)

Engine Class	2-stroke	2-stroke w/cat	Mini 4-stroke	Total
III	1,287,500	--	--	1,287,500
IV*	8,171,228	included in 2-stroke	conf	8,171,228+
V*	501,570	--	conf	501,570+
Total	9,960,298	some	conf	9,960,298+

Class IV* and V*: These numbers do not include the number of engines that are used in snowblowers and lawnmowers that do not have to meet the HC+NOx standards. Also, some of the blocks state "conf" this is done to honor the manufacturer's claim of confidentiality if only one or two companies contribute to the total number of engine families in that block.

4.1.2 Phase 2 Market Mix

To determine the Phase 2 market mix, the need for emission reduction technologies was determined by calculating an estimated overall credit balance (using Sept 1998 Phase 1 certification data) per manufacturer across Classes[30]. The likely technologies were assumed (see Table 4-04) and the percentage usages of such technologies were estimated through EPA's knowledge of technologies that manufacturers had on the marketplace or were developing. If no information was known, then the technology mix was assumed based on the most likely technology to be used. In this case it was the compression wave technologies which allow manufacturers to keep the existing production facility with minor changes. It was assumed that licensing costs and market factors would be worked out by the time this rulemaking is implemented.

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[30] The analysis accounted for engine families that would fall in the flexibility to 2008.

4.1.2.1. Potential Emission Reduction Technologies -- Potential emission reduction technologies were based on information provided in discussions with a number of industry manufacturers and independent companies. As of May 1999, a number of technologies have shown promise to meeting California ARB's 72 g/kW-hr standard which will be implemented in January 1, 2000. Three engine/equipment manufacturers are producing or intending to produce a mini four stroke engine (Ryobi, Honda and Robin America). Komatsu Zenoah has developed a stratified scavenging engine and John Deere has been promoting their LE technology engine. Other low emitting technologies, such as 2-stroke engine redesign with a catalyst, are likely to be on the California marketplace next year. Currently known technologies likely to be used to meet California ARB standards is presented in Table 4-03.

Table 4-03
Potential Emission Reduction Technologies for California ARB

Engine Technology	Potential Technologies for ARB
2 stroke	- 4-Stroke engine design - Compression Wave Technologies (ex: John Deere LE engine) - Stratified Scavenging - Improved 2 stroke with catalyst -Leaner calibration and improved engine cooling -Improved carburetor with more precise intake mixture control -Improved combustion chamber design to promote more complete combustion (more spherical and squish area) -Improved transfer port design to reduce scavenging losses -Higher manufacturing quality with reduced assembly tolerances and component variation -Optimization for a single engine operating point
4 stroke	- No changes needed

For the EPA HC+NOx standards of 50 g/kW-hr for Class III and IV, and

72 g/kW-hr for Class V[31], EPA assumes the following technologies will be utilized. Class III and IV: mini overhead valve four stroke (some small engines with catalysts[32]), stratified scavenged 2-stroke with a catalyst, compression wave engine technology with a catalyst (all catalysts are low efficiency catalysts (~30g)). Class V: stratified scavenged 2-stroke, compression wave engine technology. Redesigned 2 stroke with a higher efficiency catalyst may also be used to bring emissions lower, however more development is required to meet the proposed emission standards[33]. A list of technologies used in this analysis are listed in Table 4-04. The table also includes technologies for Class I-A and I-B which are included in this rulemaking.

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[31] It should be noted that while these engine technologies are focused on reducing HC+NOx emissions, it is expected that CO emissions will decrease due to further enleanment of the engines due to internal engine improvements made to decrease HC+NOx.

[32] Calculation of assumed in-use levels from micro four stroke engines (HC+NOx df=1.5-2.0 for four stroke), show that this technology may need a low efficiency catalyst on the smaller four stroke engines (using EPA Phase 1 certification data as of Sept 1998).

[33] Manufacturers may incorporate it on some engines families and thereby need less credits from other lower emitting engine families.

Table 4-04
Assumed Technology Improvements for This Analysis

Engine Class	Engine Design	Assumed Technologies
I-A,	2 stroke or 4 stroke	Same technologies as assumed for Classes III-V
I-B	4-stroke SV and OHV	Current technologies
III-IV	2-stroke	Four stroke OHV (smaller Class IV engines have cat) Compression Wave Technologies with a catalyst Stratified Scavenging with a catalyst (all catalysts low efficiency)
IV	4-stroke	no changes or low efficiency catalyst on smaller 4-stroke engines sizes
V	2-stroke	Compression Wave Technologies Stratified Scavenging

4.1.2.2 Extent of Use of Emission Improvement Technologies -- The standards for handheld engines are phased-in over several years (2002-2006 for Class III-IV and 2004-2008 for Class V) with the average in-use standard decreasing each year. ABT is available to these classes and across all classes. Small volume engine families in Classes III and IV and small volume manufacturers with these engine families have until 2009 to certify. Small volume engine families and manufacturers of Class V engines have until 2011 to certify.

The Phase 1 certification database (as of Sept 1998) was utilized in the analysis to determine the number of engine families and corresponding production volume that would need to incorporate emission or emission durability improvements[34] [35]. The Phase 1 certification new engine emission data for each engine family was adjusted by a deterioration factor (1.1 for HC in 2-stroke engines, 1.5 for HC in 4-stroke engines and 1.3 for HC in 2-stroke engines with a catalyst[36], NOx was kept constant) to determine the in-use emission rates. The credit equation was then applied to each engine manufacturers set of engine families. If a manufacturer's resultant credit calculation was negative (i.e.: needed credits), then it was assumed that the manufacturers would choose to improve the highest volume engine families to meet the Phase 2 standards in the early years, thereby leaving additional time for the many lower volume engine families. The emission level that was used for engines which were considered "improved" was a value of 10% below the Phase 2 standard. It was assumed that manufacturers who would reach the standard would certify slightly below the standard in order to allow the buildup of credits for smaller engine families. Table 4-05 shows the assumed engine family phase-in for all handheld classes. Table 4-06 shows the resultant engine production that are represented by the number of engine families in Table 4-05. Handheld engine families are assumed to meet the standards with conversion to mini 4-stroke and John Deere LE type technology, both with and without a catalyst. Therefore, the market mix for Phase 2, shown in Table 4-07, is assumed to be

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[34] The database contains several entrees per engine family as manufacturers show that the engine family meets the emission standard among its adjustable parameters (particularly the carburetor). For such engine families, the maximum emission rate for HC+NOx was utilized in setting the point at which the engine family emitted for Phase 1.

[35] Refer to Tables B-02 through B-06 in Appendix B for specific emission data per engine manufacturer per engine family.

[36] Based on data in SAE 941807 that tested a catalyst on a 4-stroke engine. Catalyst deterioration results were based on exhaust in and out of the catalyst - therefore assumed applicable to 2 stroke engine. MECA also provided catalyst deterioration data after the NPRM.

different than that in Phase 1.

Table 4-05
Assumed Phase-In Schedule of Handheld Engine Family Changes
(Number of Engine Families)

Engine Class	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
III	0	0	0	2	2	--	--	3	--	--
IV	13	5	8	12	18	2	--	50	--	--
V	--	--	3	1	6	3	3	--	--	21

Note that not all engine families need improvement, therefore the numbers in this table do not add up to the numbers in Table 4-01. The numbers in 2009 and 2011 are for small volume engine families/manufacturers.

Table 4-06
Production Volume (and % of Total) Represented by Engine Families

Engine Class	Specific Technology Change	Full Implementation (2010) (1998 Sales Estimates)	
		# of Engines	% Within Class
III	John Deere LE type technology w/cat, stratified charge w/cat	1,258,500	98%
IV	Mini 4-stroke, John Deere LE type technology w/cat, stratified charge w/cat	6,396,382	78%*
V	John Deere LE type technology w/cat, stratified charge w/cat	380,220	76%*

* Snowblowers using 2 stroke engines would be exempt from the HC+NOx standard due to wintertime use - the sales for snowblowers and 2-stroke lawnmowers that currently meet handheld standards are not included in this calculation. The reason for less than 100% in "% Within Class" is that some engine families can be averaged in with other engine families.

Table 4-07
Phase 2 Technology Mix in 2010
Engine Families Per Technology Type

Engine Class	Mini 4-stroke (unchanged and tech applied)	2-stroke unchanged from Phase 1	2-stroke with compression wave tech w/cat or stratified charge w/cat	Total**
III	--	2	7	9
IV	7	19	101	127
V	3	12	37	52
Total	10	33	145	188

** This analysis assumes the same number of engine families before and after Phase 2. There is the possibility that some engine families may be dropped or some may be combined in order to reduce costs. The engine families for lawnmowers and snowblowers are not included in this table (lawnmowers will have to meet a Phase 1 nonhandheld engine standard in early 2000's and snowblowers only need to met wintertime CO limits). Also, one manufacturer has exited the marketplace since the September 1998 and these engine families have been removed.

Table 4-08
Assumed Phase 2 Sales per Class and Technology Type*
(Based on Phase 1 Database as of September 1998)

Engine Class	Mini 4-stroke	2-stroke unchanged from Phase 1	2-stroke with compression wave or stratified charge w/cat	Total**
III	–	29,000	remaining	1,282,500+
IV	conf***	1,854,346	4,961,018	6,815,364+
V	--	121,350	remaining	496,570+
Total	conf	2,004,696	4,961,020	8,594,436+

* These numbers do not include the number of engines that are used in snowblowers that would not have to meet the HC+NOx standards.
** This analysis assumes no loss in engine sales
*** Some of the blocks state "conf." This is done to honor the confidentiality if only one or two companies contribute to the total number of engine families in that block. Some blocks contain "remaining" such that it does not allow calculation of confidential values.

4.2 Variable Hardware and Production Cost Estimates per Engine Class

EPA developed cost estimates for variable hardware and production costs for Phase 2 engines. The cost estimates were taken from the cost report from ICF and EF&EE (Ref 1) and manufacturer information for the variable hardware cost and production cost for each emission reduction technology per class and engine design (see Table 4-09). The information is listed and described in Chapter 3 on a per technology basis. The final variable hardware / production estimates, used in the cost-effectiveness calculation for Classes III-V engines, are listed in Appendix E (Table E-02) and are based on those numbers in Table 4-09. The value chosen from the range of cost estimates is influenced by the estimated sales production per engine family (from the Phase 1 September 1998 certification database) and assumptions about the likelihood of the latest cost estimates based on development of the technology from discussions with engine manufacturers, specifically John Deere who is developing the Compression Wave technology. EPA requests comment on the variable cost estimates used in this analysis that are contained in Table 4-09 and Table E-02 of Appendix E.

Table 4-09
Estimated Variable Hardware Costs (1998$) for Technology Changes to 2-Stroke Engines

Engine Class	Specific Technology	Hardware Variable ($)	Production Variable ($)	Licensing ($)	Total Variable ($)
III-IV	4-stroke	$10.66	$1.10	Unknown	$11.76**
	Stratified Scavenging with Catalyst	$5.00	$1.22	Unknown	$6.22**
	Compression Wave Technology with Catalyst	($4.00 to $7.50*) +$3.95	$1.11	$7.50 to $12.5+	$16.53 to $25.03+
V	Stratified Scavenging	$1.05	$0.61	Unknown	$1.66**
	Compression Wave Technology	$4.00 to $7.50*	$0.50	$15 to $22.50+	$19.50 to $30.50+
	Improved Scavenging and Combustion Chamber Design and Catalyst	$0	$0	Unknown	$0**

Source: ICF and EF&EE Cost Study to EPA(Ref. 1), MECA, and engine manufacturers
* For 500,000 and 10,000 annual production respectively (or first designed to last designed)
** Plus licensing fee, if applicable
Costs from the 1996 Cost Study (Ref. 1) were increased to 1998$ through use of GDP Implicit Price Deflators for 1996, 1997 and 1998 of 1.9%, 1.9% and 1.0% respectively.

Costs that were not included in the analysis include any additional label lettering, updated service manuals (writers, documentation) and seminars for dealers and training for technicians. The extra lettering on the label was not included for there are several options available to the manufacturer which include use of California ARB's label nationwide. While the California ARB label is not yet complete, there is discussion of a much simplified label being used. Updated service manuals and training were not specifically costed out due to the possibility that industry will find more inexpensive ways to meet the Phase 2 regulations and therefore, any overestimation of cost would account for these costs. It is also expected that the service manual updates and trainings can be incorporated during the phase-in years and prior to the phase-in years as these activities take place due to ongoing manufacturer model changes[37].

4.3 Fixed Production and R&D Cost Estimates per Engine Class

Many of the technology changes that would be required to meet Phase 2 standards require the manufacturer to expend capital on production and research and development. Production costs include new tooling machines, molds, dies and other equipment needed to produce the changed or additional parts; the costs of changing the production line to accommodate the changes in the assembly process and in the size and number of parts; and the costs of updating parts lists. Research and development (R&D) costs include engineering time and resources spent to investigate emissions on current engines, and design and prototyping of engine design changes and / or emission reduction technology. At the first sign of stringent regulations by the California ARB, small engine manufacturers began research and development activities to address emission reductions on a portion of their production. EPA has not removed any costs for manufacturers to meet California ARB's standards for 2000 and beyond since costs to apply the technologies to nationwide sales is a substantial investment[38]. If EPA were to remove any costs associated with California ARB future standards, the research and development costs for engines used in farm and construction applications that California does not regulate (includes most Class V engines) would still be applied to the federal rule.

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[37] Technologies for handheld engines are expected to be unique and require some additional training.

[38] If EPA were not setting such standards, it is possible that manufacturers may have just manufactured a portion of their product line for the California market.

Handheld classes III-V would require fixed costs for research and development and production. As previously stated, the expected technologies range from mini 4-stroke to stratified scavenged or compression wave technologies. The cost study from ICF and EF&EE and information obtained from EPA Air Docket A-96-55 Item IV-G-30 were used to estimate the fixed costs per technology presented in Table 4-10. The ICF report lists cost estimates for two cases of different annual production. The two cases are 400,000 units and 90,000 units. Analysis of the EPA Phase 1 certification database shows that, of those assumed to incorporate emission improvements, the large majority of handheld engine families are close to the 90,000 unit case and less than a dozen Class IV engine families are close to the 400,000 unit case. As a result, the cost estimates for the 90,000 unit case are used for all engine families. Docket item IV-G-30 lists estimated engine development and capital costs for the first engine developed and subsequent engine developments. These estimates were completed in December 1998 and a good amount of subsequent work has been completed and is ongoing, therefore it is estimated that these cost estimates may increase. EPA requests comment on the fixed cost estimates contained in Table 4-10. The two sets of data are combined into one through updating the 1996$ cost estimates from the Cost Study to 1998$ by multiplying by the GDP Implicit Price Deflators for 1996, 1997 and 1998.

Table 4-10
Fixed Costs For Handheld Engine Families From the
ICF Cost Study and EPA Air Docket A-96-55 Item IV-G-30
(updated to 1998$)

Engine Class	Engine Design	Technology	Fixed Production	Fixed R&D	Total Fixed Costs*
III-IV	2-stroke	4-stroke	$3,749,000	$577,000	$4,326,000
		Stratified Scavenging with Catalyst	$493,000	$561,000	$1,054,000
		Compression Wave Technology with Catalyst	$0**	$463,000-$688,000	$463,000-$688,000
V	2-stroke	Stratified Scavenging	$493,000	$173,000	$666,000
		Compression Wave Technology	$0	$75,000-$300,000	$75,000-$300,000
		Improved Scavenging and Combustion Chamber Design and Catalyst	$147,000	$357,000	$504,000

** While Docket A-96-55 Item IV-G-30 estimates no capital cost for production, it is assumed there will be some based on the extent of technology development since the estimate was made.
***Converted to 1998$ through Use of GDP Implicit Price Deflators for 1996, 1997 and 1998

The (1998$) capital costs used in the cost effectiveness calculations for all technologies is assumed to be $2,000,000 per engine family (see Appendix E Table E-03). Several reasons account for this assumption. First, it is assumed that 4-stroke technology may only be feasible for high volume engine families (which are small in number compared to data in the EPA Phase 1 certification database as of Sept 1998). Second, estimates in Table 4-10 are based on technologies preliminary development (as for the Compression Wave). Third, based on the fact that more development work is needed for they (stratified scavenged and compression wave technologies) have not yet been developed to incorporate catalysts. Work will be needed to improve engine/muffler design to accommodate cooling of the exhaust gas and muffler skin temperature which will rise, potentially several hundred degrees C, due to the use of a low to medium efficiency catalyst.[39]

Engines in Class I-A already in production in the handheld classes, particularly mini 4-stroke engines, will not require any changes due to their new engine emission level and deterioration compared to two stroke engines. Engines in Class I-B are also assumed to need no improvements.

4.4 Equipment Cost Estimates

Small engines are utilized in a wide variety of equipment from handheld trimmers to chain saws, see Table 4-11.

Table 4-11
Common Equipment Types Per Class

Class III	Class IV	Class V
trimmers	trimmers chain saw blower/vacuum pump augers	chain saw augers

The wide variety of equipment designs, and the varying ease of designing equipment which use small SI engines, presents a challenge when estimating costs for these classes of engines. Thereby, the analyses have been performed on the most common equipment types for each class as shown in Table 4-11. Data for the analysis is provided by the 1996 PSR OELINK database(Ref. 2), the EPA

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[39] Equipment which incorporate low efficiency catalysts are currently in the marketplace by Husqvarna. Others are expected due to the near future standards for handheld engines by the California ARB.

Phase 1 certification database and the ICF cost study (Ref. 1). Results from this analysis are shown in Table 4-12. These estimates are an average over all equipment engine families, types and sales per class. The actual cost increase will depend on the equipment application and flexibility of the original equipment design to incorporate a new engine.

It should be noted that this analysis has assumed the full cost of die replacement and this likely results in overestimated costs. Changes to an equipment manufacturers line (or engine/equipment manufacturers line since this industry is mostly vertically integrated) may be made more economical with planning. For instance, the timing of new dies in relation to the useful life of the existing dies can minimize an equipment manufacturer's costs. According to ICF, typical equipment dies last 3-10 years and produce upwards of 250,000 units. Due to the fact that there is substantial lead time for this rulemaking, it is expected that equipment manufacturers will purchase new dies near or at the end of the useful life of their existing dies. The few equipment only manufacturers will have to work closely with engine manufacturers to ensure the availability of engine designs in a reasonable time frame for equipment engineering requirements.

Estimates for equipment changes have been based on the estimated engine changes for Classes III-V engines. Handheld engines are expected to utilize technologies of mini four stroke and compression wave or stratified scavenged engine with (Classes III-IV) and without (Class V) catalyst[40]. At the time of this

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[40] Table E-05 contains the assumptions made in this analysis on the percentage of engine families per technology. The assumptions are based on the assumed use of four stroke and stratified scavenging by manufacturers developing or likely to use the technology and the compression wave technology was assumed to fill in the remaining need. For Class III it is assumed 71.4% of the models and engines would be compression wave with catalyst, and 28.6% stratified scavenged with catalyst. For Class IV, it is assumed 87% compression wave with catalyst,

SNPRM, EPA does not have an available resource for estimating the number of equipment models in the marketplace. Discussions with several engine manufacturers reveals that the number of models are dependent on the marketplace desire for different product from their competitors. For example, one engine may have a larger cc displacement than another engine, although it is inherently the same engine with just a slightly larger bore size, piston and rings. The EPA Phase 1 database is a source of engine manufacturers and a number of engine families. It is known that manufacturers engines are incorporated into a number of equipment types. For this analysis, EPA assumed that there were two times the number of equipment models as engine families. This is based on the assumption that there are more equipment models than engine families. It is likely that this is an underestimation of the number of equipment models. However, the equipment manufacturers are the engine manufacturers in this industry and therefore, the engine manufacturers may replace their dies during the time of die replacement which happens 1-2 times per year for large volume equipment models. Therefore the costs for this change would be minimum engineering time. However there are a larger number of engine families that are low volume and it is likely that the dies may be replaced before they are worn out. On the other hand, this may not be the case if the low volume engine families are updated on a longer lead time as allowed in this rulemaking phase-in.

As stated in the above paragraph, the majority of handheld equipment manufacturers make the engines with the exception of a few companies, such as auger manufacturers. If the current engines used by the auger manufacturers are not available upon Phase 2, then the auger manufacturers will need to

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6.5% four stroke and 6.5% stratified scavenged plus catalyst. For Class V, it is assumed 97.3% compression wave and 2.7% stratified scavenged, both without catalyst. These assumptions are for this analysis only.

incorporate changes to the auger’s transmission box in order to accommodate modifications to the engine’s speed-torque signature. EPA is aware of the number of engine families needing to be updated based on discussions with auger manufacturers.

Table 4-12
Cost Estimates For Handheld Equipment Changes (Classes III-V)

Application	Fixed Costs (per line)	Variable Hardware (per unit)	Variable Production (per unit)
4-stroke for chainsaws and trimmers	$164,670	$0	$0
4-stroke for backpack blowers and pumps	$77,189	$0	$0
Redesigned, Stratified Scavenged or Compression Wave Technology engine with a Catalyst	$298,465	$1.67	$0
Redesigned, Stratified Scavenged or Compression Wave Technology w/o cat	$30,876	$0.00	$0
Ice and Earth Augers*	$60,000	$0	$0

*Based on 1996 ICF Cost Study and discussions with and comments from (January 1998 NPRM) auger manufacturers.

4.5 Fuel Savings and Impacts on Performance

Section 213(a)(3) of the 1990 Clean Air Act requires that EPA give appropriate consideration to factors including energy, noise and safety associated with the application of technologies estimated for this rulemaking. This section discusses EPA's assessment of the effects of this proposal on energy (i.e., fuel economy) and power. Impacts on noise, safety and maintenance can be found in Chapter 3.

4.5.1 Fuel Consumption

This proposal will result in fuel savings for the consumer. This is based on the technologies to be applied on these engines to meet the Phase 2 standards as described below. The tables contained in this section present the background data utilized for estimating the fuel consumption per engine per class. These data were inputted into the NONROAD model to calculate the fuel savings per year for all equipment types given scrappage rates, growth, engine power, engine load factor, residential or commercial usage and useful life. No assumption was used for changes in fuel consumption as engines age over time. Additional calculations for number of barrels reduced and resultant cost savings is presented in Chapter 7 on Aggregate Costs and Economic Analysis.

4.5.1.1. Handheld Equipment -- For 2-stroke handheld engines in Classes III-V, EPA estimates that the technologies of mini-four stroke, stratified scavenging and compression wave will result in a 30% decrease in fuel consumption (see Tables 4-14 and 4-15). This is based on an estimate that expected Phase 2 technology will reduce the approximate 30 percent of the fuel that exits the engine unburned due to fuel scavenging and incorporate technologies that will result in improved fuel combustion, thereby allowing the manufacturers to enlean the engine. Limited publicly available test data, contained in Table 4-13, illustrates the basis for the expected fuel usage due to Phase 2 technology.

Table 4-13
Fuel Consumption of Class III to V 2-Stroke Engines
(NOTE: weightings have been changed from 90/10 to 85/15)

Manufacturer	BSFC (g/kWh)	Reference
Class III		
NA	NA	NA
Class IV		
Husqvarna E-tech	556	Testing at EPA
John Deere LE Prototype	585	Testing at John Deere
Komatsu Zenoah Stratified Scavenged	475	Testing at EPA
Class V		
NA	NA	NA

NA=not available

4.5.1.2. BSFC Values and Estimated Fuel Savings -- The values listed in Tables 4-14 and 4-15 contain the fuel consumption values utilized to estimate fuel savings for Phase 1 and Phase 2 engines, respectively, using the NONROAD model.

Table 4-14
Phase 1 Fuel Consumption Estimates Per Engine Per Class (g/kWh)

Engine Class	OHV	Other	2-Stroke
III	--	--	720
IV	515	--	720
V	--	--	529

Source: Small Engine Phase 1 RSD(Ref. 3)

Table 4-15
Phase 2 Fuel Consumption Estimates Per Engine Per Class (g/kWh)

Engine Class	OHV	Other	2-Stoke
III	--	--	504
IV	515	--	504
V	--	--	370

4.5.2 Power

The power from handheld engines redesigned to utilize sonic wave technology is not expected to change. For engine redesigned to use a stratified charge design, the engine power would be expected to decrease slightly without a change in the engine size, however engine manufacturers would be expected to increase the size of the engine to obtain similar power to Phase 1 engines. EPA requests comments and information on the trade-off between power, emissions performance, and cost in redesigning an engine.

Chapter 4 References

1. ICF and Engine, Fuel and Emissions Engineering, Incorporated; "Cost Study For Phase Two Small Engine Emission Regulations", Draft Final Report, October 25, 1996, EPA Air Docket A-96-55, Docket Item #IV-A-01.

2. Power Systems Research, OELINK database, St. Paul, Minnesota, 1996.

3. US EPA, "Regulatory Impact Analysis and Regulatory Support Document Control of air Pollution; Emission Standards for New Nonroad Spark-Ignition Engines At or Below 19 Kilowatts", May 1995, EPA Air Docket A-93-25, Docket Item # V-B-01.

Chapter 5: Compliance Program Costs

The Phase 1 rule is a "new engine certification only" rule in that the standards need only be met after a short number of break-in hours (less than 12 hours) prior to production and SEA. This proposed Phase 2 regulation would bring the concepts of useful life and emission deterioration to the emission regulation of handheld small spark ignited engines at or below 19kW. These program elements work to assure that actual production engines meet standards throughout their useful lives.

The costs accounted for in this chapter are those costs that are above those required in Phase 1. Appendix C contains the detailed cost spreadsheet results for each compliance program. A summary of the cost results for each program per engine class and the overall cost methodology is included at the end of this chapter. Reductions in costs for small volume engine manufacturers or small volume engine families are accounted for in this analysis.

5.1 Background

General assumptions and cost estimates for the various compliance programs for handheld engines are described herein.

5.1.1 Engine Families

The program costs are calculated on the number of engine families per class. This data is taken from EPA’s Phase 1 certification database as of September 1998 (Appendix C contains nonconfidential database information). While a reliable source for engine families for the Phase 1 program, EPA expects that manufacturers may make changes during the years in which the Phase 2 program is in effect. However, it is difficult to predict these changes at this time. Consequently, this analysis makes no assumption as to a different number of engine families from the Phase 1 database. The costs associated with record keeping requirements for each program is included in the ICR's submitted with this rulemaking.

5.1.2 Assumed Costs

The number of break-in hours and the costs for bench age hours and emission testing for this analysis are included in Table 5-01.

Table 5-01
Common Costs Among Compliance Programs

Topic	Estimate	Resource
Hours for break-in	Classes III-V: 4.2	Average from EPA Phase 1 certification database.
Bench age ($/hour)	$15.00	EMA/OPEI NPRM Comments
Emission test ($)	$300.00	EPA estimate from "Cost Study for Phase Two Small Engine Emission Regulations", ICF and EF&EE, October 25, 1996 (Ref. 1) and other industry data.

5.2 Certification

The Phase 2 rule continues the fundamental certification program that began in Phase 1. The most significant additional component to certification that affects all engines under Phase 2 is the need to predict emissions for an engine family to its full useful life. This is done, for all engine classes, through bench aging up to the chosen useful life hours. A deterioration factor must also be established for the engine family to be used in conducting the Production Line Testing program and therefore the engine must be tested two times. The first time is just after break-in and the second is at the end of its useful life. Small volume engine families and engine families of small volume manufacturers may utilize assigned deterioration factors(df) for the specific engine design. This analysis assumes that manufacturers of small volume engine families and small volume engine manufacturers do use an assigned df after the initial emission test.

5.2.1. Cost Inputs and Methodology-- As stated previously, the number of engine families chosen for the various useful lives was determined through examination of EPA's Phase 1 certification database as of September 1998 and assumptions of each engine manufacturer's market tendencies (see Table 5-02). EPA assumes that the same number of engine families certified today will be certified in the Phase 2 program.

EPA estimated the number of engine families certified to the individual useful life categories. The basis of the estimation was the industry to which the manufacturer was known, be it low cost consumer or high quality commercial. No split was made between engine families within an engine manufacturer (in other words, assuming a portion was for consumer and a portion was for commercial). For the 50 hour useful life category, EPA assigned those manufacturers, and related engine families, geared toward the consumer market. For the 300 hour useful life category, EPA considered those manufacturers, and related engine families, with ties to the automotive market. Lastly, for the 125 hour useful life, EPA assumed the remaining engine manufacturers and related engine families.

EPA assumes that certification occurs twice per engine family throughout the phase-in of the Phase 2 standards. This is assumed due to the fact that the standards are average standards for all Classes and all engine families must be certified the first year to which they are applicable, whether or not they are in their final Phase 2 configuration. EPA assumes carryover for certification will be used until the engines are updated for emission compliance at which time they will be recertified. All families are included in the analysis based on the analysis, with ABT, of engine manufacturers engine families which shows that the large majority of handheld engine families will likely be updated due to the magnitude of difference in the emission standards from Phase 1 to Phase 2.

Costs for the emission tests, break-in hours, and bench aging (on a dynamometer) are listed in Table 5-01. (A summary of the total certification costs per year (2002-2011) per class are listed in Table 5-04.) Certification costs are treated as fixed costs and are amortized at a rate of 7% over 5 years.

Table 5-02
Number of Phase 1 Certification Families per Useful Life Category Assumptions for Handheld Engine Classes

Engine Class	Useful Life Category			Small Volume
	50	125	300	
III	4	1	1	3
IV	15	33	24	54*
V	1	2	18	30*

* The total number of Class IV and Class V families assumed in the certification cost analysis was underestimated by one family in each class. This discrepancy will be corrected for the final rule analysis.

It is not easy to estimate the number of Class I-A engine families that will be certified, for Class I-A is for handheld engine families that are used in nonhandheld applications. Assuming all are certified to Class I-A, the estimated number of small volume engine families in Table 5-02 hold for Class I-A (with the exception of Class V for Class I-A is for engines from 0-65cc and the standard for Class I-B is more stringent than standards in Class V). For Class I-B, the EPA

1998 certification database shows that two of three engine families that would fall into Class I-B would be small volume. EPA is aware of at least one engine family not yet certified, however the sales production estimate is unknown.

5.3 Averaging, Banking and Trading

Averaging, banking and trading (ABT) will enable handheld manufacturers to comply with the HC + NOx standard on a sales-weighted average basis. By essentially allowing a manufacturer to produce some engines that exceed the standards when it can generate or obtain offsetting credits from engines that are below the standards, the ABT program will reduce the capital costs of complying with the Phase 2 standards. Manufacturers will be able to distribute capital across engine families to obtain the most cost effective emission reductions, as long as the ABT calculation is acceptable to prove compliance to the standards. The optional ABT program adds no costs to the certification process, but does necessitate limited tracking of engines for credit accounting purposes. Related costs are addressed in the certification ICR's for this program. While the ABT program is optional for all engine manufacturers, this analysis assumes that all engine manufacturers will utilize this option. The analyses also assumes that manufacturers will work to optimize the number of engine families that will need to be improved to meet the emission standards in this proposal. Optimization is achieved by choosing those engine families that have high emission rates and high production volumes that will result in influencing the manufacturers' production weighted average the most.

5.4 Production Line Testing

5.4.1 Rationale for Production Line Testing

The certification process is performed on prototype engines selected to represent an engine family. A certificate of conformity indicates that a manufacturer has demonstrated its ability to design engines that are capable of meeting standards. Production line testing indicates whether a manufacturer is able to translate those designs into actual mass production engines that meet standards.

Manufacturer run Production Line Testing (Cum Sum) is a new program to the EPA requirements for small engines. Therefore all of the costs are allocated to the Phase 2 program. Note that engine manufacturers will be conducting quality audit testing for California's ARB and therefore will likely utilize the same data for EPA's PLT program[41]. However, it is likely that manufacturers do not sell all of their product line for use in California and therefore will incur additional costs to test their whole product line. Since the estimated volume per engine family per manufacturer sold in California is unknown, and likely varies amongst engine manufacturers, no costs were subtracted for CARB quality audit testing.

5.4.2 Cost Inputs and Methodology

All engine manufacturers will conduct PLT and it is to be conducted on each engine family certified to the standard each year. Testing will be performed on 2-30 engines. A value of 7 tests per engine family are assumed for this analysis. PLT is performed on new engines and therefore an initial engine break-in and emission test is required. Table 5-03 contains the assumed engine family phase in schedule for the PLT program.

All engine families would be required to be tested beginning with the first year of the phase-in. The average break-in hours for each engine per class, emission test costs and break-in costs were utilized in this analysis as described

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[41] If the data are from 50 state engine families sold nationwide and if the test engines are appropriately selected and tested.

in Table 5-01. A summary of the PLT costs per year (2002-2027(Class III and IV) and 2004-2027 for Class V) per class for the requirements in this section are listed in Table 5-05.

Table 5-03
Assumed Engine Family Phase-In Per Class Per Year

Year	Class III	Class IV	Class V
2002	6	72	--
2004	--	--	21
2009	3	54	--
2011	--	--	30

PLT performed for each engine family, regardless if same engine certified with various fuel specifications
Number of engine families taken from EPA Phase 1 certification database as of September 1998

5.5 Cost Summary Tables

The costs for each program were estimated in 1996, 1997 and 1998. The GDP Implicit Price Deflator for 1996, 1997 and 1998 were used to bring all costs to 1998. Tables 5-04 to 5-05 present the estimated costs for the certification and PLT compliance programs, respectively, as incurred through 2011 (see Appendix C for complete analysis to 2027 in the form of recovered costs). The total estimated compliance program costs are presented in Table 5-06. The administrative costs for these programs are included in the ICR's for this proposal.

Chapter 7 determines the uniform annualized cost and cost per engine for this rulemaking (with costs as recovered).

Table 5-04
Resultant Fixed Certification Costs Per Class Per Year
As Incurred (1998$)

Year	Class III	Class IV	Class V
2002	$13,080	$225,586	$0
2003	$0	$0	$0
2004	$0	$0	$98,468
2005	$0	$0	$0
2006	$13,080	$225,586	$0
2007	$0	$0	$0
2008	$0	$0	$98,468
2009	$926	$16,673	$0
2010	$0	$0	$0
2011	$0	$0	$9,263

Table 5-05
Resultant Production Line Testing Costs
As Incurred (1998$)

Year	Class III	Class IV	Class V
2002	$15,614	$187,366	$0
2003	$15,614	$187,366	$0
2004	$15,614	$187,366	$54,648
2005	$15,614	$187,366	$54,648
2006	$15,614	$187,366	$54,648
2007	$15,614	$187,366	$54,648
2008	$15,614	$187,366	$54,648
2009	$15,614	$187,366	$54,648
2010	$15,614	$187,366	$54,648
2011	$15,614	$187,366	$54,648

Table 5-06
Total Compliance Program Costs Per Class
As Incurred (1998$)

Year	Class III	Class IV	Class V
2002	$28,694	$412,952	$0
2003	$15,614	$187,366	$0
2004	$15,614	$187,366	$153,116
2005	$15,614	$187,366	$54,648
2006	$28,694	$412,952	$54,648
2007	$15,614	$187,366	$54,648
2008	$15,614	$187,366	$153,116
2009	$16,540	$204,038	$54,648
2010	$15,614	$187,366	$54,648
2011	$15,614	$187,366	$63,911
2012	$15,614	$187,366	$54,648
2013	$15,614	$187,366	$54,648
2014	$15,614	$187,366	$54,648
2015	$15,614	$187,366	$54,648
2016	$15,614	$187,366	$54,648
2017	$15,614	$187,366	$54,648
2018	$15,614	$187,366	$54,648
2019	$15,614	$187,366	$54,648
2020	$15,614	$187,366	$54,648
2021	$15,614	$187,366	$54,648
2022	$15,614	$187,366	$54,648
2023	$15,614	$187,366	$54,648
2024	$15,614	$187,366	$54,648
2025	$15,614	$187,366	$54,648
2026	$15,614	$187,366	$54,648
2027	$15,614	$187,366	$54,648

Chapter 5 References

1. ICF and Engine, Fuel and Emissions Engineering, Incorporated; "Cost Study For Phase Two Small Engine Emission Regulations", Draft Final Report, October 25, 1996, EPA Air Docket A-96-55, Docket Item #IV-A-01.

Chapter 6: Environmental Benefit

This chapter presents the methodology used by EPA to quantify the emission reduction benefits that would be realized through the proposed Phase 2 HC+ NOx in-use emission standards for small SI handheld engines. Benefits, in terms of HC+NOx emission reductions, are presented in the form of aggregate benefits by engine class. These benefits are estimated in terms of future 49-state emission reductions from affected small SI engines used in a variety of equipment types. Estimated benefits illustrate the potential future effect of the proposed standards on the emission inventory. Air quality benefits are discussed qualitatively for all pollutants.

Many of the detailed results discussed below are presented in separate tables included in Appendix F. EPA has replaced the model that it used in the NPRM analysis with a new computer model called the NONROAD model, to predict the emissions impact of the new standards that have been finalized. Much of the information used in the new NONROAD model is the same as the information used in the NSEEM model for the NPRM. The following sections highlight areas where differences exist between modeling performed for the proposal and that for the final rulemaking.

For a complete description of EPA's NONROAD model, the reader is referred to the technical reports and program documentation prepared by EPA in support of NONROAD model development. Copies of the technical reports and model documentation are available at EPA's web site for nonroad modeling (http:/www.epa.gov/omswww/nonrdmdl.htm).

6.1 Estimated Emissions Reductions

To estimate the average annual emissions at baseline (Phase 1), EPA calculated the tons per year estimates based on revised Phase 1 Emission Factors. The in-use factors have now been determined as a multiplicative rather than an additive (as was the case for the Phase 1 rule-making) function of new engine emission factors and a deterioration factor which is a function of engine hours of use. As before, total emissions are calculated for each type of equipment using the equation :

$$MASS_{i,j}=N_{i,j}\times HP_{i,j}\times LOAD_i\times HOURS_i\times EF_{i,j}$$

Where,

$N_{i,j}$ = nationwide population of i^{th} equipment type using engine j

$Hp_{i,j}$ = average rated horsepower of engine j used in equipment type i

$LOAD_i$ = ratio (%) between average operational power output and rated power for the i^{th} equipment type

$HOURS_i$ = average annual hours of usage for the i^{th} equipment type

$EF_{i,j}$ = brake specific in-use emission rate (kilowatts/hr) for engine type j used in equipment i

$MASS_{i,j}$ = annual nationwide emissions (grams) for the j th engine type used in equipment i

For the benefits analysis described here, EPA performed separate calculations for the major equipment categories, each one of which is equipped with one or more of 7 different engine types with average power ratings as displayed in Table F-01 in Appendix F. Population and activity information used to construct the inventories relied predominantly on data available in a commercially available marketing research data base that includes most types of nonroad equipment (Ref. 1). This information is presented in Tables F-02 and F-03 in Appendix F.

6.1.1 Aggregate HC+ NOx Reductions

The calculation of aggregate HC+ NOx reductions is described in this section. The calculation takes into account U.S. population of small SI handheld engine/equipment types, hours of use, average power rating and related equipment scrappage rates as described below. Along with estimated values for Phase I in-use engine emission rates and proposed Phase II in-use engine emissions standards, EPA has determined nationwide annual emissions under the baseline and controlled scenarios through calendar year 2027.

6.1.1.1 In-use Population --In order to estimate future emission totals, some projections of future populations of Phase1 and Phase 2 controlled engines are needed. The NONROAD model has determined population estimates of nonroad equipment covered by the proposed standards using certain growth factors. For the base population estimates, the NONROAD model uses the 1996 population estimates from the Power Systems Research (PSR) PartsLink database. To check on PSR population estimates, the population for several high sales applications (i.e.: trimmers, blowers and chainsaws) were checked, using historical sales data and engine manufacturer production estimates from the EPA 1998 certification database, and were adjusted accordingly. For this rule making, the population estimates were adjusted to exclude engines that are covered by California’s Small Off-Road regulations.

6.1.1.2 Growth Estimates -- The NONROAD model projects future year (post-base year) equipment populations by applying a growth rate to the base year equipment population. The determination of the growth rate uses a methodology which is different from that used for the Phase 1 rule making. For a detailed description of population growth in the various categories of Handheld Equipment the reader is referred to an AWMA paper presented by EPA at the AWMA Emission Inventory Conference, New Orleans, LA on 12/9/98 titled "Geographic Allocation and Growth in EPA’s Nonroad Emission

Inventory Model".

However, it should be recognized that, while national growth is measured at the level of the economy as a whole, growth in specific areas of the country is likely to vary from area to area in response to the specific demographic and commercial trends in those areas. These effects should be taken into account in estimating growth at the local level.

6.1.1.3 Scrappage-- The NONROAD model uses a scrappage curve to determine the proportion of equipment that has been scrapped as a function of equipment age. The default scrappage curve used in the NONROAD model is based on a cumulative Normal Distribution representing accumulated scrappage at various ages. The scrappage curve is scaled to the average lifetime of the equipment such that half of the units sold in a given year are scrapped by the time those units reach the average expected life and that all units are scrapped at twice the average life expectancy. The median life of the different handheld equipment types are presented in Table F-03 in Appendix F.

6.1.1.4 Emission Factors -The in-use emission factors for the pre-control (Phase 1) scenario were recalculated based on revised new engine values obtained from EPA’s 1998 Phase 1 Certification database. For the Phase 2 scenario, the new engine emission factor values were back-calculated using 1) the proposed in-use emission factors (Phase 2 standards) and 2) a multiplicative deterioration factor.

The deterioration values for HC, NOx and CO were taken from the original Phase 1 rulemaking. The ratio of maximum emission level and the new engine level, from Phase 1 engines in the Phase 1 rulemaking, was used as a multiplicative deterioration factor in the NONROAD model. This value was used in the nonroad model DF equation, see below, to equal “1+A”. This methodology for determining deterioration factors was applied to both Phase 1 and Phase 2 scenarios and was used only for HC and CO. All NOx deterioration factors were set to 1.0.

The exhaust emission factors for HC, NOx and CO along with those for Fuel Consumption are displayed in Table F-04 in Appendix F. The table also lists the value of the constant A, the slope of the deterioration factor equation for all nonhandheld engines, which takes the form:

$$\begin{aligned} DF &= 1 + A*(\text{Agefactor})^{0.5} && \text{for agefactor}<1.0 \\ &= 1+ A && \text{for agefactor} >=1.0 \end{aligned}$$

For a detailed explanation of the deterioration factor function, the reader is referred to EPA's technical report no. NR-011 , titled "Emission Deterioration Factors for the NONROAD Emissions Model".

6.1.1.5 Emissions reductions -- EPA calculated baseline emissions using revised in-use emission factors for Phase 1. To obtain average annual emissions for engines controlled to the levels that would be required to comply with EPA's proposed Phase2 emission standards , emissions were recalculated using post-control activity and in-use Phase 2 emission factors (see Table F-04 in Appendix F).

Table F-05 in Appendix F presents total annual nationwide emissions from engines addressed in this rule under both the baseline (Phase1) and the controlled (Phase 2) scenario. The nationwide emissions are shown graphically in Figure 6-01. In Figure 6-01, the annual benefit of the proposed regulation in terms of reduction in total exhaust HC+NOx is indicated by the difference between the upper and lower curves. The area between the curves represents the net benefit of the regulation during the time required for the nonroad small SI handheld engine and equipment fleet to completely turn over. The averaged results indicate that the standards represent on average a 77.8% reduction in annual HC+NOx emissions from handheld engines from Phase 1 levels to which the standards apply, by year 2027.

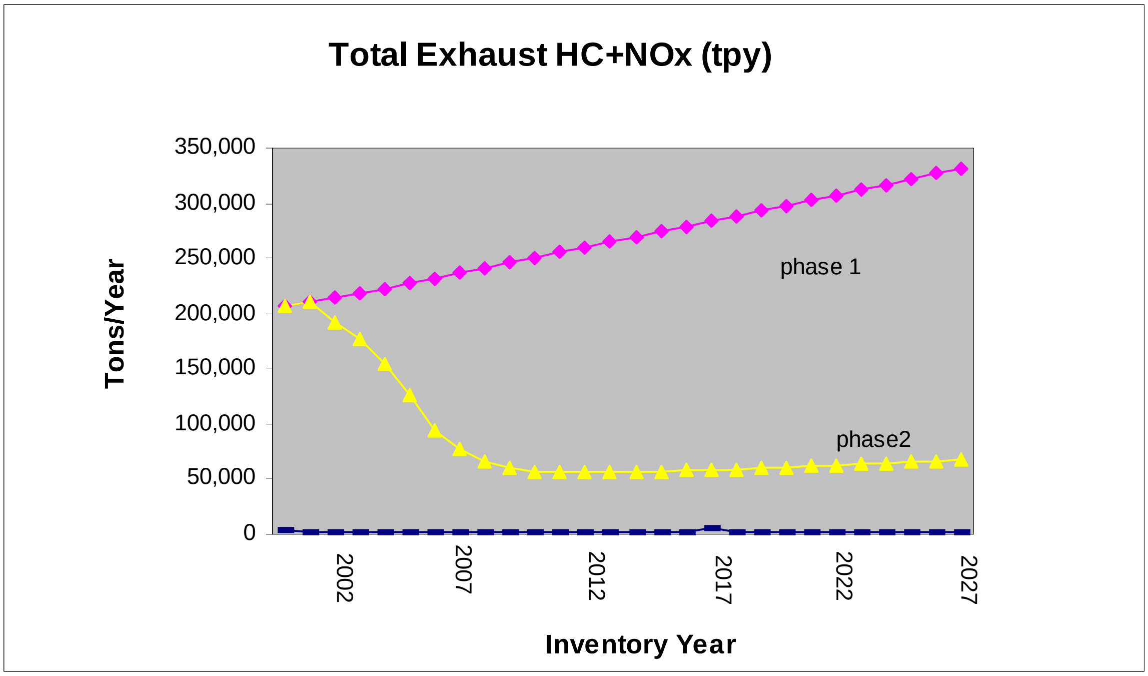

Figure 6-01

In addition, the proposed rule is expected to reduce Fuel Consumption in handheld engines by approximately 30% from Phase1 levels by year 2027 . This will have a beneficial impact on HC refueling losses.

6.2 Air Quality Benefits

Air quality benefits associated with reduction in VOC emissions are discussed in this section. Health and welfare effects of the pollutants as they impact on ozone formation are described.

6.2.1 VOC

EPA expects that reducing VOC emissions from small nonroad spark ignition engines will help to mitigate the health and welfare impacts of ambient HC on urban and regional tropospheric ozone formation and transport.

6.2.1.1 Health and Welfare Effects of VOC Emissions--VOC is the general term used to denote volatile organic compounds, a broad class of pollutants encompassing hundreds of specific toxic compounds, primarily Benzene and 1,3 Butadiene as well as aldehydes and gasoline vapors. As stated previously, VOC is a precursor to ozone for which the EPA has established a NAAQS. Measures to control VOC emissions should also reduce emissions of hazardous air pollutants (HAPs). However, the magnitude of reduction will depend on whether the control technology reduces the individual HAPs in the same proportion that total VOCs are reduced. Since nonroad engines have significant VOC impacts , they are expected to have significant impacts on HAPs as well.

Nonroad sources contribute substantially to summertime VOC and NOx emissions and winter CO emissions. The median contribution of total nonroad emissions to VOC and NOx inventories in summer, and CO inventories in winter, ranges from 7.4-12.6% VOC, 14.5-17.3% NOx, and 5.2-9.4% winter CO, depending on the area (Ref. 4). The lawn and garden equipment category is a major contributor to summertime VOC emissions, accounting for a median ranging from 2.4% to 4.7% of the total VOC inventory in tons per summer day, depending on the area.

6.2.2 Benzene

Benzene is a clear, colorless, aromatic hydrocarbon which has a characteristic odor. It is both volatile and flammable. Benzene contains 92.3% carbon and 7.7% hydrogen with the resulting chemical formula C_6H_6. Benzene is present in both exhaust and evaporative emissions. Data show the benzene level of gasoline to be about 1.5%. Some exhaust benzene is unburned fuel benzene. Some benzene also forms from engine combustion of non-aromatic fuel hydrocarbons. The fraction of benzene in the exhaust varies depending on control technology and fuel composition and is generally about 3 to 5%. The fraction of benzene in the evaporative emissions also depends on control technology and fuel composition and is generally about 1%.

Mobile sources account for approximately 65% of the total benzene emissions, of which 30% can be attributed to nonroad mobile sources (Ref. 2). For nonroad engines, benzene was estimated to be about 3.0% of VOC emissions and 1.7% of evaporative VOC emissions. The split between exhaust and evaporative benzene emissions was assumed to be 80% exhaust to 20% evaporative. Thus, the overall benzene fraction of nonroad VOC emissions was estimated to be 2.7%.

6.2.2.1 Projected Benzene Emission Reductions--Nonroad engines account for approximately 20% of the total benzene emissions with 45% attributed to highway motor vehicles and 35% to stationary sources. Many of the stationary sources attributed to benzene emissions are industries producing benzene as a by-product or use benzene to produce other chemicals.

Since benzene levels generally decrease proportionally to overall HC emissions, once newer emission control technology is applied, the amount of benzene produced by new small SI engines should be reduced further from Phase 1 if this rule is adopted and becomes effective.

6.2.2.2 Health Effects of Benzene Emissions--Health effects caused by benzene emission differ based on concentration and duration of exposure. EPA's Total Exposure Assessment Methodology (TEAM) Study identified the major sources of exposure to benzene for much of the U.S. population. These sources turn out to be quite different from what had previously been considered as important sources. The study results indicate that the main sources of human exposure are associated with personal activities, not with the so-called "major point sources". The results imply that personal activities or sources in the home far outweigh the contribution of outdoor air to human exposure to benzene. Since most of the traditional sources exert their effect through outdoor air, some of the nonroad small SI engine sources could explain the increased personal exposures observed. The TEAM Study is described in detail in a four-volume EPA publication (Ref.3) and in several journal articles (Ref. 4)(Ref.5) .

The average ambient level of benzene ranges from 4.13 to 7.18 $\mu g/m^3$, based on urban air monitoring data. A crude estimate of ambient benzene contributed by < 19kW SI engine sources can be calculated by multiplying the total ambient concentration by the percentage of nonroad engine-produced benzene. This figure must be adjusted then to reflect time spent indoors and in other micro environments by using the factor developed in the Motor-Vehicle-Related Air Toxics Study. Applying the nonroad adjustment factor of .25 and integrated adjustment factor of .622 to reflect only nonroad exposure to benzene, the range becomes .642 to 1.12 $\mu g/m^3$.

Based on data from EPA's NEVES (Ref.6), the exhaust and crankcase emissions from a 2.9 kW (3.9 hp) lawnmower with a 4-stroke engine contain 3.5 grams of benzene. A 2.9 kW (3.9 hp), 2-stroke lawnmower exhaust has 17 grams of benzene. A small, 2.2 kW (3 hp) chainsaw emits 28.2 grams of benzene per hour, compared to a large, 4.5 kW (6 hp) chainsaw that emits 40.8 grams per hour. No study as yet has been conducted on the health effects of benzene emissions specifically from small SI engines.

A separate study conducted at Southwest Research Institute (SWRI) reported a 2-stroke, 4.5 kW(6hp) moped engine fueled with industry average unleaded gasoline emitted 2,260 mg/hph of benzene. A 4-stroke walk-behind mower powered by an overhead valve, 2.6 kW (3.5 hp) engine emitted 690 mg/hph of benzene when fueled with average unleaded gasoline.

Concentration and duration of exposure to benzene are especially important to consider in the case of small SI engine applications, since the operator is typically in the direct path of the exhaust given out by the engine. Rate of dilution of the exhaust by the air surrounding the engine depends on local weather conditions.

6.2.2.3 Carcinogenicity of Benzene and Unit Risk Estimates--The International Agency for Research on Cancer (IARC), classified benzene as a Group I carcinogen . A Group I carcinogen is defined as an agent that is carcinogenic to humans. IARC (1987) based this conclusion on the fact that numerous case reports and follow-up studies have suggested a relationship between exposure to benzene and the occurrence of various types of leukemia. The leukemogenic (i.e., the ability to induce leukemia) effects of benzene exposure were studied in 748 white males employed from 1940-1949 in the manufacturing of rubber products in a retrospective cohort mortality study (Ref. 7). Statistics were obtained through 1975. A statistically significant increase in the incidence of leukemia was found by comparison to the general U.S. population. The worker exposures to benzene were between 100 ppm and 10 ppm during the years 1941-1945. There was no evidence of solvent exposure other than benzene. In addition, numerous investigators have found significant increases in chromosomal aberrations of bone marrow cells and peripheral lymphocytes from workers with exposure to benzene (IARC 1982).

Exposure to benzene has also been linked with genetic changes in humans and animals. EPA has concluded that benzene is a Group A, known human carcinogen based on sufficient human epidemiologic evidence demonstrating an increased incidence of nonlymphocytic leukemia from occupational inhalation exposure. The supporting animal evidence showed an increased incidence of neoplasia in rats and mice exposed by inhalation and gavage. EPA (Ref. 8) calculated a cancer unit risk factor for benzene of 8.3×10^{-6} $(\mu g/m^3)^{-1}$ based on the results of the above human epidemiological studies in benzene-exposed workers in which an increase of death due to nonlymphocytic leukemia was observed. EPA's National Center for Environmental Assessment (NCEA) of the office of

Research and Development (ORD) has recently announced a Notice of Peer-Review Workshop and Public Comment Period to review an external review draft document titled, *Carcinogenic Effects of Benzene: An update (EPA/600/P-97/001A)*. EPA will consider comments and recommendations from the workshop and the public comment period in document revisions.

The California Department of Health Services (DHS, 1984), which provides technical support to CARB, has also determined that there is sufficient evidence to consider benzene a human carcinogen. CARB performed a risk assessment of benzene that was very similar to EPA's risk assessment. The CARB risk estimate is actually a range, with the number calculated by EPA serving as the lower bound of cancer risk and a more conservative (i.e., higher) number, based on animal data , serving as the upper bound of cancer risk. The CARB potency estimate for benzene ranges from 8.3×10^{-6} to 5.2×10^{-5} µg / m^3.

A number of adverse noncancer health effects have also been associated with exposure to benzene. People with long-term exposure to benzene at levels that generally exceed 50 ppm (162,500 µg / m^3) may experience harmful effects on the blood-forming tissues, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components, such as red blood cells and blood platelets, leading to anemia and a reduced ability to clot. Exposure to benzene at comparable or even lower levels can be harmful to the immune system, increasing the chance for infection and perhaps lowering the body's defense against tumors by altering the number and function of the body's white blood cells. In studies using pregnant animals, inhalation exposure to benzene in the range of 10-300 ppm (32,500-975,000 µg / m^3) indicates adverse effects on the developing fetus, including low birth weight, delayed bone formation, and bone marrow damage.

6.2.3 1,3- Butadiene

1,3-Butadiene is a colorless, flammable gas at room temperature with a pungent, aromatic odor, and a chemical formula C_4H_3. 1,3-Butadiene is insoluble in water and because of its reactivity is estimated to have a short atmospheric lifetime. The actual lifetime depends upon the conditions at the time of release, such as the time of day, intensity of sunlight, temperature etc. 1,3-Butadiene is formed in vehicle exhaust by the incomplete combustion of the fuel and is assumed not to be present in vehicle evaporative and refueling emissions. The contribution of 1,3 -butadiene from Nonroad Sources to Nationwide Toxic Emissions Inventory is 21.2% (Ref. 2).

6.2.3.1 Projected 1,3-Butadiene Emission Reductions--Current EPA estimates (Ref.2) indicate that mobile sources account for approximately 68% of the total 1,3-butadiene emissions, out of which 31% can be attributed to nonroad mobile sources. The remaining 1,3-butadiene emissions come from stationary sources mainly related to industries producing 1,3-butadiene and those industries that use 1,3-butadiene to produce other compounds. 1,3-Butadiene emissions appear to increase roughly in proportion to exhaust hydrocarbon emissions. Since hydrocarbons are decreased by the use of a catalyst on a motor vehicle, 1,3-butadiene emissions are expected to decrease proportionally with the use of any emission control technology that decreases total hydrocarbon emission.

6.2.3.2 Health Effects of 1,3 - Butadiene Exposure--The annual average ambient level of 1,3-butadiene ranges from 0.12 to 0.56 $\mu g/m^3$. According to data from EPA's NEVES, 1,3-Butadiene content in exhaust and crankcase from a 2.9 kW (3.9 hp), 4-stroke lawnmower is approximately 1.5 gms/hr of usage. For a 2.9 kW (3.9 hp), 2-stroke lawnmower, 1,3-butadiene content in exhaust is 7.0 grams per hour. Butadiene emitted from small, 2.2 kW (3hp) chainsaw is approximately 12.2 grams per hour from a large 4.5 kW (6 hp) chainsaw.

A separate study conducted at SwRI revealed a 2-stroke, 4.5 kW (6 hp) moped engine emitted 207 mg/kW-hr (154 mg/hp-hr) when fueled with industry average unleaded gasoline. A 2.6 kW (3.5 hp) overhead valve, walk-behind mower emitted 209 mg/kW-hr (156 mg/hp-hr) of 1,3-butadiene when fueled with industry average unleaded gasoline. Since 1,3-butadiene levels normally decrease proportional to overall hydrocarbons once emission control technology is applied, 1,3-butadiene levels are expected to be less from new small SI engines if this rule is adopted and becomes effective . This, in turn, will reduce risk of exposure to 1,3-butadiene produced by these sources.

6.2.3.3 Carcinogenicity of 1,3-Butadiene--Long-term inhalation exposure to 1,3-butadiene has been shown to cause tumors in several organs in experimental animals. Epidemiologic studies of occupationally exposed workers were inconclusive with respect to the carcinogenicity of 1,3-butadiene in humans. Based on the inadequate human evidence and sufficient animal evidence, EPA has concluded that 1,3-butadiene is a Group B2, probable human carcinogen. IARC has classified 1,3-butadiene as a Group 2A, probable human carcinogen. EPA calculated a cancer unit risk factor of $2.8X10^{-4}$ $(\mu g/m^3)^{-1}$ for 1,3-butadiene based on the results of a study in mice in which an increase in the incidence of tumors in the lung and blood vessels of the heart, as well as lymphomas were observed. EPA's Office of Research and Development is currently in the process of releasing an updated 1,3-butadiene risk assessment factor.

Exposure to 1,3-butadiene is also associated with adverse noncancer health effects. Exposure to high levels (on the order of hundreds of thousands ppm) of this chemical for short periods of time can cause irritation of the eyes, nose, and throat, and exposure to very high levels can cause effects on the brain leading to respiratory paralysis and death. Studies of rubber industry workers who are chronically exposed to 1,3-butadiene suggest other possible harmful effects including heart disease, blood disease, and lung disease. Studies in animals indicate that 1,3-butadiene at exposure levels of greater than 1,000 ppm (2.2X106 $\mu g/m^3$) may adversely affect the blood-forming organs. Reproductive and developmental toxicity has also been demonstrated in experimental animals exposed to 1,3-butadiene at levels greater than 1,000 ppm.

6.2.4 CO

The Clean Air Act directs the Administrator of the EPA to establish National Ambient Air Quality Standards (NAAQS) for several widespread air pollutants, based on scientific criteria and allowing for an adequate margin of safety to protect public health. The current primary and secondary NAAQS for CO are 35ppm for a 1-hour average and 9ppm for an 8-hour average.

According to the Nonroad Study, a 4-stroke, 2.9 kW (3.9 hp) lawnmower engine emits 1051.1 g/hr CO while a 2-stroke, 2.9 kW (3.9 hp) engine meets 1188.4 g/hr CO. A separate study conducted at SwRI revealed that a 2-stroke moped engine fueled with typical unleaded gasoline emits 184 g/kW-hr (137 g/hp-hr) of CO. A 4-stroke, 2.6 kW overhead valve, walk-behind mower fueled with typical unleaded gasoline emits 480 g/kW hr (358 g/hp-hr) of CO.

Although the proposed Phase 2 emission standards for handheld small SI engines does not include significantly more stringent standards for CO, reductions in CO beyond Phase 1 levels, due to improved technology, is also to be expected by year 2025.

6.2.4.1 Health and Welfare Effects of CO--The EPA has documented the detrimental health effects that CO can have on populations(Ref. 9). Carbon monoxide is a colorless, odorless, tasteless and nonirritating gas and gives no signs of its presence. It is readily absorbed from the lungs into the bloodstream, there forming a slowly reversible complex with hemoglobin (Hb) known as carboxyhemoglobin (COHb).

Blood COHb levels do not often exceed 0.5 to 0.7% in normal individuals unless exogenous CO is breathed. Some individuals with high endogenous CO production can have COHb levels of 1.0 to 1.5% (e.g. anemics). The presence of COHb in the blood reduces the amount of oxygen available to vital tissues, affecting primarily the cardiovascular and nervous systems. Although the formation of COHb is reversible, the elimination half-time is quite long because of the right binding between CO and Hb. This can lead to accumulation of COHb, and extended exposures to even relatively low concentrations of CO may produce substantially increased blood levels of COHb.

Health effects associated with exposure to CO include cardiovascular system, central nervous system (CNS), and developmental toxicity effects, as well as effects of combined exposure to CO and other pollutants, drugs, and environmental factors. Concerns about the potential health effects of exposure to CO have been addressed in extensive studies with various animal species as subjects. Under varied experimental protocols, considerable information has been obtained on the toxicity of CO, its direct effects on the blood and other tissues, and the manifestations of these effects in the form of changes in organ function. Many of these studies, however have been conducted at extremely high levels of CO (i.e., levels not found in ambient air). Although severe effects from exposure to these high levels of CO are not directly germane to the problems from exposure to current ambient levels of CO, they can provide valuable information about potential effects of accidental exposure to CO, particularly those exposures occurring indoors.

All gasoline-powered engines produce carbon monoxide. Carbon monoxide poisoning can cause permanent brain damage , including changes in personality and memory. Once inhaled, carbon monoxide decreases the ability of the blood to carry oxygen to the brain and other vital organs. Even low levels of carbon monoxide can set off chest pains and heart attacks in people with coronary artery disease.

Although no studies measuring the human health effects of CO emanating from small SI engine exhaust have been conducted, ample research results are available concerning general health effects of exposure to CO . The effects of exposure to low concentrations-such as the levels found in ambient air - are far more subtle and considerably less threatening than those occurring in direct poisoning from high CO levels. Maximal exercise performance in healthy individuals has been shown to be affected at COHb levels of 2.3% and greater. Central nervous system effects, observed at peak COHb levels of 5% and greater, include reduction in visual perception, manual dexterity, learning, driving performance, and attention level. Of most concern, however, are adverse effects observed in individuals with chronic heart disease at COHb levels of 3 to 6%. At these levels, such individuals are likely to have reduced capacity for physical activity because they experience chest pain (angina) sooner. Exercise-related cardiac arrhythmias have also been observed in some people with chronic heart disease at COHb levels of 6% or higher and may result in an increased risk of sudden death from a heart attack .

The NAAQS set by EPA are intended to keep COHb levels below 2.1% in order to protect the most sensitive members of the general population (i.e., individuals with chronic heart disease). However, elderly people, pregnant women (due to possible fetal effects), small children, and people with anemia or with diagnosed or undiagnosed pulmonary or cardiovascular disease are also likely to be at increased risk for CO effects.

Since small SI engines are typically used in applications that require the operator to be near, and perhaps in the direct path of the exhaust, the effects of exhaust CO on the operator of the engine is a matter of concern. Although no studies measuring the human health effects of CO emanating from small SI engine exhaust have been conducted, laboratory animal studies reveal that CO can adversely affect the cardiovascular system, depending on the laboratory conditions utilized in these studies.

6.2.4.2 Developmental Toxicity and Other Systemic Effects of Carbon monoxide--Studies in laboratory animals of several species provide strong evidence that maternal CO exposures of 150 to 220 ppm, leading to approximately 15 to 25% COHb, produce reductions in birth weight, cardiomegaly, delays in behavioral development, and disruption in cognitive function (Ref. 10). Human data from cases of accidental high CO exposures (Ref. 11) are difficult to use in identifying a low observed-effect level for CO because of the small numbers of cases reviewed and problems in documenting levels of exposure.

Behaviors that require sustained attention or sustained performance are most sensitive to disruption by COHb. The group of human studies (Ref. 12) on hand-eye coordination (compensatory tracking), detection of infrequent events (vigilance), and continuous performance offer the most consistent and defensible evidence of COHb effects on behavior at levels as low as 5%. These effects at low CO-exposure concentrations, however, have been very small and somewhat controversial. Nevertheless, the potential consequences of a lapse of coordination, vigilance, and the continuous performance of critical tasks by operators of machinery could be serious.

At higher levels of exposure, where COHb concentrations exceed 15 to 20%, there may be direct inhibitory effects of CO resulting in decreases in xenobiotic metabolism , which might be important to individuals receiving treatment with drugs. Inhalation of high levels of CO, leading to COHb concentrations greater than 10 to 15%, have been reported to cause a number of other systemic effects in laboratory animals as well as humans suffering from acute CO poisoning. There are reports in the literature of effects on liver, kidney, bone, and immune capacity in the lung and spleen (Ref. 13). It generally is agreed that these effects are caused by severe tissue damage occurring during acute CO poisoning.

Chapter 6 References

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Chapter 7: Analysis of Aggregate Costs

This chapter develops the uniform annualized cost per class and the average cost per equipment per class for this rulemaking. This chapter also assesses the cost-effectiveness, in terms of dollars per ton of total emission reductions. This analysis relies on cost information from Chapters 4 and 5 and emissions information from the small engine model[42] presented in Chapter 6. Lastly, this chapter discusses possible economic effects of the regulation and compares the cost effectiveness of the new provisions with the cost-effectiveness of other HC+NOx control strategies from previous EPA rulemakings.

7.1 Aggregate Cost Analysis for the Period 2002 to 2027

The analysis examines total annual costs of the proposed standards for all applicable engines[43] from 2002-2027. (EPA analyzed costs over the period from 2002 to 2027 to ensure that the fleet was completely turned over to Phase 2 engines.) The complete year-by-year stream of costs over time that are summarized in this section can be found in Appendix E. The uniform annualized cost per class and average cost per equipment per class are calculated. Costs of variable hardware, production, research and development, and compliance programs are used and annualized where appropriate. Cost

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[42] The nonroad small engine emission model accounts for factors including various equipment types, consumer or professional usage, lifetime of the equipment, scrappage, etc., see Chapter 6.

[43] The analysis covers all engines sold in the United States except those sold in California which are covered by rulemakings established by CARB.

savings due to reduced fuel consumption are also addressed, including the valuation of the reduced fuel consumption to the consumer. Total costs to society are presented as the aggregate costs to consumers with and without fuel savings.

This analysis is based on cost estimates for variable and fixed costs from the 1996 ICF and EF&EE cost study, comments to the January 1998 NPRM and manufacturer data. The 1996 cost estimates are adjusted by the GDP Implicit Price deflator for 1996, 1997 and 1998 for costs in 1998$. The costs for the compliance program were based on costs in 1997 and are also adjusted accordingly.

This analysis also accounts for estimates of the increased profits to economic entities in the various levels of industry, including the engine manufacturer, equipment manufacturer, and mass merchandiser. As rationalized in Appendix E, full cost pass through and profitability on increased costs are assumed. Table 7-01 summarizes the assumed profitability factors, sometimes referred to as retail price equivalent factors, which were applied to specific costs in this analysis, to estimate the price increase to the consumer.

Table 7-01
Profitability Factors
(Retail Price Equivalent Factors)

Level	Factor
Engine/Equipment Manufacturer	0.16
Mass Merchandiser	0.05

In the handheld industry, the vast majority of equipment manufacturers also manufacture the engine, therefore separate markups are not applied.

These factors were applied to the specific variable engine and equipment manufacturer costs identified in this chapter. For example, EPA has estimated some variable hardware costs and production costs specific to engines and specific to equipment. From the consumer's point of view, the engine/equipment specific costs were marked up 22%.

7.1.1 Uniform Annualized Costs

A uniform annualized cost is an expression of the equal annual payments that would be equivalent to a given cash flow schedule for a known interest rate. This expression of an annualized cost was chosen due to the variety of the programs that makeup this Phase 2 regulation. The methodology used for calculating the uniform annualized costs is as follows.

The EPA Phase 1 certification database was utilized to determine the number of engines, and related number of models, that would likely be improved during the course of the phase-in (see Tables E-01 to E-03). The costs per engine (variable and fixed costs) for emission improvements were estimated from the information listed in Chapter 4. The variable costs per engine are then multiplied by the number of engines in that year[44] to incorporate that technology or set of technologies. The fixed costs are amortized for five years for the engine and ten years for equipment starting in the phase-in years in which they are calculated to be recovered.

In order to determine the uniform annualized costs, the annual costs were discounted to the first year the Phase 2 standards are implemented, 2002 and 2004, for handheld engines at a rate of seven percent (the consumption rate of

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[44] The future sales growth estimates are based on the 1998 Phase 1 certification database industry production estimates and the growth assumptions utilized in the nonroad model for the main types of equipment from 2002-2027 (average percentage increases (2%) are used for 1999-2001). The population estimates from the nonroad model are converted to yearly percentage increases and then these percentages are applied to the 1998 estimated production to calculate resultant sales estimates for future years. EPA has not assumed any impact of increased cost for Phase 2 engines on future sales. EPA requests information and comments related to the effect of increased cost on sales for this industry or similar industry that would help EPA is analyzing this possible impact.

interest). The uniform annualized cost was obtained by summing the discounted costs over the appropriate time period and dividing by the appropriate present worth factor (at an interest rate of 7% over the corresponding number of years). The sections below address each cost category separately. Section 7.3. contains the full 20 year analysis of total cost of the final standards.

7.1.1.1. Variable Costs -- Table 7-02 contains the uniform annualized variable costs per class with consumer markup (see Table E-08 for costs per year on which this table is based). The results are calculated to first year of implementation which is 2002 for Classes III and IV, 2004 for Class V.

Table 7-02
Uniform Annualized Variable Cost per Class
With Consumer Markup, for the Period 2002 to 2027
($Thousands, 1998$)

Engine Class	Engine	Equipment	Total
III	$26,195	$2,297	$28,492
IV	$209,845	$12,023	$221,868
V	$8,843	$280	$9,123

7.1.1.2. Capital Costs -- Engine improvements, and thereby capital expenditures, are phased-in over time for Classes III-V. The phase-in and number of models for all Classes were determined in Chapter 4. Capital costs are estimated to be recovered over 5 years for engines and 10 years for equipment, at a 7 percent interest rate. Costs incurred prior to the initial year of the Phase 2 rulemaking were moved to the first year of the rulemaking (i.e., the first year in which costs are recovered) using a 7 percent interest rate.

Potential capital cost increases include costs for development and application of engine designs with reduced emissions and costs for production facilities.

EPA has estimated the uniform annualized fixed costs as shown in Table 7-03. The results are calculated to first year of implementation which is 2002 for Classes III-IV and 2004 for Class V. Appendix E contains the tables on which this table is based.

Table 7-03
Uniform Annualized Fixed Cost per Class, for the Period 2002 to 2027
($Thousands, 1998$)

Engine Class	Engine	Equipment	Total
III	$2,002	$324	$2,326
IV	$32,909	$4,262	$37,171
V	$10,563	$280	$10,843

7.1.1.3. Compliance Costs -- This rulemaking accounts for those costs that are above and beyond those for the Phase 1 program. These costs are the compliance program costs presented in Chapter 5. Compliance costs include costs for certification and production line testing (PLT). Certification costs are treated as fixed costs and production line testing costs are treated as variable costs for this analysis. Appendix E and Chapter 5 contain details on the program costs assumed for the compliance programs. The estimates for the administrative burden for these programs are estimated in the supporting statements for the Information Collection Requests submitted to OMB. These supporting statements contain estimates of the testing, record keeping, and reporting burden on industry that would occur under the proposed regulations.

Table 7-04 contains the uniform annualized compliance costs for all classes. The results are calculated to first year of implementation which is 2002 for Classes III-IV and 2004 for Class V.

Table 7-04
Uniform Annualized Compliance Programs, for the Period 2002 to 2027
($Thousands, 1998$)

Engine Class	Cost
III	$64
IV	$961
V	$459

The total uniform annualized costs for this rulemaking are presented in Table 7-05.

Table 7-05
Total Uniform Annualized Costs
Including Consumer Markups, for the Period 2002 to 2027
($Thousands, 1998$)

Engine Class	Cost
III	$30,882
IV	$259,999
V	$40,925
Total	$331,806

Classes III and IV annualized to 2002, Class V to 2004

7.1.1.4. Fuel Savings -- As explained in Chapter 4, the technological changes necessary to bring these engines into compliance with the proposed emission standards would cause a decrease in fuel consumption of approximately 30% for handheld engines. The tons/year savings per class (see Appendix E) are converted to gallons/year and then multiplied by $0.802/gallon

(1998$ adj by GDP) to determine the fuel savings[45]. Table 7-06 contains the uniform annualized fuel savings for all equipment types in each class which have been discounted 7% to the first year of implementation for each class[46]. The total value is for all classes discounted to the year 2002 for Classes III and IV and 2004 for Class V. Table E-07 contains the yearly fuel savings information on which this analysis is based.

Table 7-06
Uniform Annualized Fuel Savings
and Comparison to Uniform Annualized Cost, for the Period 2002 to 2027
($Thousands, 1998$)

Engine Class	Uniform Annualized Fuel Savings	Uniform Annualized Cost	Resultant Costs
III	$2,916	$30,882	$27,966
IV	$32,271	$259,999	$227,728
V	$5,596	$40,925	$35,329
Total	$61,764	$331,806	$270,042

* Classes III and IV to 2002, Class V to 2004

7.1.2 Average Cost Per Equipment

The average cost per equipment changes over time due to the recovering of capital costs and the increased production over which costs can be spread. Therefore this analysis calculates a range of cost that is based on the uniform annualized cost. Since the production of these engines is assumed to increase

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[45] EPA estimated the value of gasoline at $0.765 per gallon, based on the average refinery price to the end user in 1995 from the Energy Information Administration.

[46] Implementation dates are 2002 for Classes III and IV, 2004 for Class V.

over the years of this analysis, this section presents a range of cost per equipment estimates. The uniform annualized cost is divided by the production in the first full implementation year (2006/2008) and the last year (2027) accounted for in this analysis. Results are shown in Table 7-07. An average of this range is also presented. Note that this table shows the costs and savings spread across all equipment within each engine class and not only those equipment whose engines will incorporate technology changes.

Table 7-07
Average Cost Per Equipment per Engine Class
Based on Uniform Annualized Costs(1998$)

Engine Class	Cost in First Year (III : 2006 IV: 2006 V: 2008)	Cost in 2027	Average Cost
III	$20.31	$14.38	$17.35
IV	$26.72	$18.97	$22.85
V	$62.66	$44.19	$53.43

7.1.2.1. Fuel Savings -- The resultant fuel savings per engine per class is calculated in the same manner as the cost per equipment. The uniform annualized fuel savings is divided by the production in the years 2006 (Classes III and IV) and 2008 (Class V) and 2027 to yield a range of costs for this analysis. The resultant cost per engine is then calculated by subtracting the fuel savings per engine from the total cost per equipment. Both results are listed in Table 7-08 below.

Table 7-08
Fuel Savings and Resultant Cost per Equipment
Based on Uniform Annualized Analysis (1998$)

Engine Class	Average Cost Per Equipment	Average Savings Per Equipment	Average Resultant Cost Per Equipment
III	$17.35	$0.50	$16.85
IV	$22.84	$1.02	$21.82
V	$53.42	$3.04	$50.38

NOTE: This table shows the costs and savings spread across all equipment within each engine class and not only those equipment whose engines which will incorporate technology changes.

The differences seen in the handheld classes (Classes III-V) in Table 7-08 are due to influential factors contained in the nonroad small engine emission model from which they were calculated. Such factors include application, useful life, scrappage curve, and engine power. For example, Class V engines are higher in power and thereby the fuel savings are more notable. Class IV engines are assumed to see a higher savings per engine, likely also due to the higher power in this class than from Class III engines.

The overall increase in price per equipment per engine class is significant, in some classes, compared to the selling price of the equipment in which small SI engines are used. Handheld equipment in Classes III include trimmers which can be found in the marketplace for $70.00. An increase of $17.35 per equipment is 25% of this price. Equipment in Class IV include trimmers, chainsaws and blowers for both consumer and commercial use. These equipment sell for approximately $200.00 and the increase of $22.84 is 11% of this price. Class V equipment includes professional use chainsaws which sell for approximately $400.00. An increase of $53.42 is 13% of this price.

7.2 Cost Effectiveness

The following section describes the cost effectiveness of the proposed HC+NOx standards for the various Classes of handheld small SI engines. As discussed in Chapter 4, the estimated cost of complying with the provisions varies depending on the model year under consideration. The following section presents the total cost effectiveness over all of the model years after the standards take effect. These cost effectiveness numbers are calculated by taking the net present value of the total costs per year (including amortized capital and variable costs) over the 27 year time line, discounted by 7%, and dividing it by the net present value of the emission benefits discounted by 7%. Table 7-09 presents the resulting cost effectiveness results.

Table 7-09
Cost Effectiveness of Reproposed Phase 2 Rulemaking for Handheld Engines

Scenario	Cost Effectiveness ($/ton)
Without Fuel Savings	$2,146
With Fuel Savings	$1,911

Note that while the costs were based on the John Deere LE technology, it is thought that the anticipated licensing fee (ranging from $7.50 to $15+ per engine) would have a great impact on the overall cost effectiveness of the rulemaking. For comparison, the cost effectiveness was calculated with an assumed one third of the licensing fee in EPA Docket A-96-55, Item IV-G-30. The results were $1,714 without fuel savings and $1,480 with fuel savings. These numbers are for comparison only.

In an effort to evaluate the cost-effectiveness of the proposed handheld (HH) engine standards, EPA has summarized the cost effectiveness results for several other recent EPA mobile source rulemakings. Table 7-10 summarizes the cost effectiveness results from the Phase 2 Nonhandheld(NHH) Small SI final rule(Ref. 2), the Small SI Engine Phase 1 rulemaking, the SI Recreational Marine Engine rulemaking(Ref. 3) and the recently final standards for nonroad compression-ignition (CI) engines (Ref. 4).

Table 7-10
Cost Effectiveness of Other Like Rulemakings
(With Fuel Savings)

Rulemaking	Cost Effectiveness	Pollutants
Small SI, Phase 2 HH, SNPRM	$1,911	HC+NOx
Small SI, Phase 2 NHH, FRM (Ref 1.)	$1,562	HC+NOx
Small SI, Phase 1, FRM (Ref 2.)	$280	HC+NOx
SI Recreational Marine, FRM (Ref 3.)	$1,000	HC
Nonroad CI, Tier 2/3 for various model year groupings within Tiers, FRM (Ref 4)	$0-$540	HC+NOx

7.3 20-Year Cost Analysis

Table 7-11 contains the year by year fleet wide costs and emission benefits associated with the reproposed small SI Phase 2 handheld engine standards of the 20 year period from 2002-2021. EPA has performed an aggregate costs analysis over a twenty year time frame in response to a request from the Office of Management and Budget. Fuel savings are not included for they significantly dilute the costs to the manufacturers. The GDP Implicit price deflators for 1996-1998 were included to compute the costs per year based on 1996 and 1997 cost estimates for technology and compliance program costs respectively. (The numbers presented in Table 7-11 are not discounted).

Table 7-11
Costs and Emission Benefits
of the Reproposed Small SI Phase 2 Handheld Engine Standards
for the 20 year Cost Analysis
(Fuel Savings Not Included)
1998$

Calendar Year	Fleetwide Costs	Fleetwide HC+NOx Reductions (short tons)
2002	$189,062,144	21,800
2003	$190,943,463	40,818
2004	$214,919,019	68,468
2005	$288,606,766	100,437
2006	$363,337,166	136,116
2007	$377,084,909	157,692
2008	$371,980,433	172,503
2009	$436,008,285	182,390
2010	$429,128,602	189,398
2011	$437,834,292	195,200
2012	$418,577,602	200,001
2013	$418,514,983	204,372
2014	$368,919,788	208,511
2015	$373,196,672	212,489
2016	$356,075,254	216,738
2017	$361,123,923	220,519
2018	$366,620,696	224,269
2019	$367,924,933	227,991
2020	$373,281,568	231,691
2021	$378,597,737	235,366

Table 7-12 contains the discounted year by year fleet wide costs and emission benefits associated with the reproposed small SI Phase 2 handheld engine standards for the 20 year period from 2002 to 2021. The year by year results were discounted to 2002 and a discount rate of seven percent was assumed for the analysis.

Table 7-12
Discounted Costs and Emission Benefits
of the Reproposed Small SI Phase 2 Handheld Engine Standards
for the 20 year Cost Analysis
(Fuel Savings Not Included)
1998$

Calendar Year	Fleetwide Costs	Fleetwide HC+NOx Reductions (short tons)
2002	$189,062,144	21,800
2003	$178,451,835	38,148
2004	$187,718,594	59,802
2005	$235,589,090	81,987
2006	$277,188,184	103,842
2007	$268,856,328	112,432
2008	$247,866,269	114,946
2009	$271,524,047	113,584
2010	$249,756,753	110,231
2011	$238,152,845	106,176
2012	$212,783,628	101,671
2013	$198,833,453	97,096
2014	$163,804,798	92,582
2015	$154,863,351	88,175
2016	$138,092,122	84,055
2017	$130,887,929	79,926
2018	$124,187,114	75,968
2019	$116,475,611	72,176
2020	$110,440,546	68,549
2021	$104,685,429	65,081

Summing the discounted annual costs and discounted emission reductions over the twenty year period yields a 20-year fleet wide cost of $3.799 billion and 20-year emission reductions of 1.688 million tons of HC+NOx. The resulting 20 year annualized fleet wide costs and emission reductions are $359 million per year and 159,357 tons per year of HC+NOx. The spreadsheets prepared for this analysis are contained in Appendix E. The reader is directed to the spreadsheets for a complete version of the analysis.

7.4 Fuel Savings

Table 7-13 contains the year by year fleet wide gallon and monetary fuel savings associated with the reproposed small SI Phase 2 handheld engine standards of the 20 year period from 2002-2021. (The numbers presented in Table 7-13 are not discounted).

Table 7-13
Fuel Savings of the Reproposed Small SI Phase 2 Handheld Engine Standards for the 20 year Cost Analysis
(1998$)

Calendar Year	Fleetwide Savings	Fleetwide Savings (gallons)
2002	($5,086,044)	(6,339,412)
2003	($9,379,907)	(11,691,422)
2004	($15,913,161)	(19,834,684)
2005	($23,325,619)	(29,073,814)
2006	($31,643,529)	(39,441,529)
2007	($36,693,630)	(45,736,139)
2008	($40,279,258)	(50,205,383)
2009	($42,635,231)	(53,141,944)
2010	($44,327,426)	(55,251,152)
2011	($45,746,968)	(57,020,516)
2012	($46,930,512)	(58,495,723)
2013	($48,006,697)	(59,837,115)
2014	($49,023,527)	(61,104,526)
2015	($49,993,300)	(62,313,282)
2016	($51,008,002)	(63,578,040)
2017	($51,913,927)	(64,707,215)
2018	($52,808,738)	(65,822,536)
2019	($53,695,273)	(66,927,542)
2020	($54,574,949)	(68,023,999)
2021	($55,445,640)	(69,109,257)

Table 7-14 contains the discounted year by year fleet wide gallon and related monetary fuel savings associated with the proposed small SI Phase 2 handheld engine standards for the 20 year period from 2002 to 2021. The year by year results were discounted to 2002 and a discount rate of seven percent was assumed for the analysis.

Table 7-14
Discounted Fuel Savings
of the Proposed Small SI Phase 2 Handheld Engine Standards
for the 20 year Cost Analysis
(1998$)

Calendar Year	Fleetwide Savings	Fleetwide Savings (gallons)
2002	($5,086,044)	(6,339,412)
2003	($8,766,268)	(10,926,563)
2004	($13,899,171)	(17,324,381)
2005	($19,040,653)	(23,732,892)
2006	($24,140,697)	(30,089,753)
2007	($26,162,051)	(32,609,235)
2008	($26,839,770)	(33,453,967)
2009	($26,551,079)	(33,094,132)
2010	($25,798,965)	(32,156,673)
2011	($24,883,320)	(31,015,383)
2012	($23,857,093)	(29,736,259)
2013	($22,807,636)	(28,428,182)
2014	($21,767,032)	(27,131,140)
2015	($20,745,442)	(25,857,797)
2016	($19,781,783)	(24,656,660)
2017	($18,815,996)	(23,452,872)
2018	($17,888,147)	(22,296,370)
2019	($16,998,548)	(21,187,546)
2020	($16,146,758)	(20,125,847)
2021	($15,331,181)	(19,109,285)

Summing the discounted gallon and related monetary fuel savings over the twenty year period yields a 20-year fleet wide savings of $395 million and 20-year fuel savings of 493 million gallons. The resulting 20 year annualized fleet wide costs and emission reductions are $37 million per year and 47 million gallons per year. The spreadsheets prepared for this analysis are contained in Appendix E. The reader is directed to the spreadsheets for a complete version of the analysis.

Chapter 7 References

1. "Phase 2 Emission Standards for New Nonroad Spark-Ignition Nonhandheld Engines At or Below 19 Kilowatts; Final Rule", EPA Air Docket A-96-55, Docket Item V-A-01.

2. "Control of Air Pollution; Emission for New Nonroad Spark-ignition Engines At or Below 19 Kilowatts; Final Rule", US EPA, Federal Register, vol 60, No. 127, Monday, July 3, 1995, 40 CFR part 90, pg 34596.

3. "Air Pollution Control; Gasoline Spark-Ignition Marine engines; New Nonroad Compression-Ignition and Spark-Ignition Engines, Exemptions; Rule", US EPA, Federal Register, vol 61, No. 194, Friday October 4, 1996, 40 CFR parts 89, 90 and 91, pg 52100.

4. ""Final Regulatory Impact Analysis: Control of Emissions from Nonroad Diesel Engines", August 1998, EPA Air Docket A-96-40, Item # V-B-01.

Chapter 8: Assessment of Impacts on Small Entities

8.1 Introduction and Methodology

As part of the January 1998 Notice of Proposed Rulemaking for Phase 2 emission standards for small spark-ignition (SI) engines below 19 kilowatts, EPA prepared a Draft Regulatory Impact Analysis (RIA). The RIA for the January 1998 proposal included an analysis of the types of entities, including small entities, that were subject to the rule, a determination of the potential degree of impact on the small entities, and a determination as to whether a Regulatory Flexibility Analysis should be conducted, based on the significance of the impact and the number of small entities impacted. However**,** in response to comments on the January 1998 proposal and more recent information, EPA decided to finalize emission standards for nonhandheld engines only, and to address emission standards for handheld engines (i.e., classes III, IV, and V) in a separate Supplemental Notice of Proposed Rulemaking (SNPRM). EPA is proposing more stringent standards for these handheld engines, which will require more effort on the part of the affected engine and equipment manufacturers for compliance.

8.1.1 Regulatory Flexibility

The Regulatory Flexibility Act (RFA), 5 U.S.C. 601 *et seq.* generally requires EPA to conduct a regulatory flexibility analysis of any rule subject to notice and comment regulatory requirements, unless the agency certifies the rule "will not, if promulgated, have a significant economic impact on a substantial number of small entities." Small entities include small businesses, small not-for-profit organizations, and small governmental jurisdictions. As noted in the RIA for the January 1998 proposal, small not-for-profit organizations and small governmental jurisdictions are not expected to be impacted by this rulemaking, thus the January 1998 RIA focused on small businesses, specifically on the impact of the proposed rule on handheld engine and equipment manufacturers.

8.1.2 Methodology.

The January 1998 RIA relied on information from a cost study and a small business impact study performed by ICF Incorporated under a contract with EPA, to determine the economic impact of the proposed regulations on small entities.(Ref. 1) (Ref. 2) The primary data sources for the small business impact analysis included the EPA Phase 1 Certification database, the Power Systems Research OELINK (PSR) database, and the Dun & Bradstreet Market Identifiers Online (D&B) database.

The cost study also relied on the PSR database for engine and sales data, and incorporated the results of an engineering analysis that was performed to analyze the costs of compliance with the Phase 2 emission standards. This analysis also relies on the latter study and on the PSR and D&B databases for data on handheld engine and equipment manufacturers. This information is supplemented with information received from engine and equipment manufacturers, trade associations and from engine and equipment manufacturer websites.

To evaluate the impacts of the proposed rule on small entities, an economic measure known as the "sales test" was used, which measures compliance costs as a function of sales revenue. After determining the costs of compliance to the manufacturers, these costs are annualized and expressed as a percentage of annual sales revenue. EPA’s guidance for this is based on the percentage of small entities that are affected by costs of compliance amounting to varying percentages of sales. Although there are a number of specific scenarios, the guidance provides that if any number of small entities are affected by less than one percent of their sales income, or if fewer than 100 small entities are affected by more than one percent of their annual sales income, this does not amount to a "substantial number" of small entities.

The RFA specifies that the Small Business Administration (SBA) definitions for small business should be used for the initial determination of a small entity, however, EPA may use an alternative definition of small business where appropriate. The SBA defines small business by category of business using Standard Industrial Classification (SIC) codes, and in the case of manufacturing, generally defines small business as a business having 500 employees or less. However, for engine manufacturers (SIC code 3519) the cutoff is 1,000 employees. Table 8-01 shows the range of primary SIC codes listed for the engine and equipment manufacturers identified, and the corresponding SBA small business cutoff, based on number of employees.

Table 8-01
Small Business Engine and Equipment Manufacturer Definitions

SIC Code	Applicable	Title	Employees
3519	Engine	Internal Combustion Engines	1,000
3523	Equipment	Farm Machinery & Equipment	500
3524	Equipment	Lawn & Garden Equipment	500
3531	Equipment	Construction Machinery	750
3561	Equipment	Pumps and Pumping Equipment	500
3621	Equipment	Motors and Generators	500

8.2 Impact on Engine Manufacturers.

8.2.1 Small Business Engine Manufacturer Impacts

8.2.1.1. Identification of Manufacturers -- The PSR database shows that there are 22 primary handheld engine and equipment manufacturers. D&B financial data were available for twenty of the 22. One of the remaining two appears to be a large multinational firm which markets on five continents, and must be assumed to be large. The other will be assumed to be small for purposes of this analysis. Under these assumptions, sixteen of the 22 are large businesses, many of which also manufacture nonhandheld engines. These firms account for more than 90 percent of the total estimated handheld engine production. Six are small entities, all of which are also equipment manufacturers. Three of the six account for 97 percent of the total estimated production for the small business entities. At least one of the small firms also manufactures nonhandheld equipment.

8.2.2 Expected Technologies/Costs

The cost of compliance for handheld engines depends on technology employed by engine manufacturer to meet the emission standards. Handheld manufacturers employ a much higher percentage of 2-stroke cycle engines than nonhandheld applications, which could increase the difficulty of compliance with the relatively more stringent proposed standards. As noted in Chapter 3, EPA expects that most handheld manufacturers will meet the new standards using improved 2-stroke technologies such as compression wave or stratified scavenging technologies, in some cases with the addition of a catalyst. Such improved 2-stroke technologies are under development to meet the California Phase 2 standards, and catalyst technology has already been in use on some chainsaws to meet the EPA Phase 1 standards. The agency estimates that costs for these technologies will range from slightly over $5 per engine to $28 per engine, depending on type of technology and engine family production volume, and that application of a catalyst will add $6.71 to these totals.

Other handheld manufacturers may elect to convert to 4-stroke cycle engines. Two mini-4-stroke engines have recently appeared on the market, and a third is under development. EPA expects that significant numbers of 4-stroke engines will be used in meeting the proposed Phase 2 standards. Based on the ICF cost study and other information that has come to the attention of the agency, EPA estimates that the cost of converting a handheld engine 2-stroke family to 4-stroke would be approximately $10 per engine, for the production levels involved. As noted in Chapter 3, EPA has also become aware of other engine technology developments in the area of ignition and induction improvements which may assist 2-stroke engines in meeting the Phase 2 standards.

8.2.3 Expected Impact on Small Business Entities

To estimate impacts on engine manufacturers, specific compliance costs were developed for each engine manufacturer based on the type of engine modification needed and the level of engine production. The individualized annualized compliance costs were then estimated for each small ultimate parent company identified. Table 8-02 summarizes these costs. A more detailed technology analysis is available Chapters 3 and 4, and in the ICF cost report.

Table 8-02
Engine Modifications and Associated Costs

Engine Class	Engine Modification	Fixed Cost	Variable Cost Per Engine
III, IV, V	Conversion to OHV technology	$4,125,000	$9.93
III, IV, V	Compression wave technology	$2,000,000	$12-28
III, IV, V	Stratified scavenge technology	$2,000,000	$5.21
III, IV	Add catalyst (metallic substrate)	$108,000	$6.71
	Manufacturer Conf Technology	conf	conf

Source: U.S. Environmental Protection Agency, *Cost Study for Phase Two Small Engine Emission Regulations*, prepared by ICF/Engine Fuel Emissions, October 1996 and discussions with manufacturers.

8.2.4 Sales Test for Engine Manufacturers

A compliance cost-to-sales ratio was calculated for each small ultimate parent company for which D&B data were available. D&B data were available for five of the six small handheld engine manufacturers. Under the proposed standards, these manufacturers will likely achieve compliance with the proposed standards through improvements to their existing engines, with the addition of catalysts in some cases. Under this scenario, the annualized costs of compliance for the three largest firms, which account for 97 percent of the production for small business entities, amounted to between 0.6 and 1.6 percent of sales. The costs of compliance for two of the three smallest firms were calculated at less than 0.5 and 15 percent of sales, respectively. Since D&B data were not available for the third manufacturer, it was not possible to calculate a compliance cost in terms of percent of sales. However, this manufacturer has already certified to California Phase 2 emission standards, and should not be faced with as great a burden in meeting the proposed standards as other less advanced companies. Compliance with the proposed standards therefore does not appear to represent a "significant burden on a substantial number" of small entities according to the SBREFA criteria. Also, as will be seen below, all three of these smallest firms qualify for the small manufacturer flexibilities that are proposed for handheld engine manufacturers.

8.2.5 Flexibilities Case

EPA is proposing a number of small-volume flexibilities which can ease the burden of compliance on the smallest entities. There are two major small-volume flexibilities proposed to be offered to benefit the small engine manufacturers:

(1) Small volume engine manufacturers are defined as those manufacturers which produce less than 25,000 units per year for handheld applications. Small volume manufacturers could sell Phase 1 engines for 3 years beyond last date of standards phase-in. Small volume engine manufacturers would also be allowed to use assigned deterioration factors and to opt out of Production Line Testing,

but could not participate in Averaging, Banking and Trading programs.

(2) Small volume engine families are defined as families consisting of less than 5,000 units for handheld model lines. The flexibilities and restrictions for small volume engine families are the same as for small volume manufacturers.

The two small volume manufacturers which would be impacted more than three percent of sales by the proposed standards would cease to be impacted at such levels if they were to take advantage of the small volume manufacturer flexibility. In addition, the three larger small-entity engine manufacturers could take advantage of the small engine family flexibilities for some 35 percent of their engine families. This would allow a more orderly transition to the new emission standards and minimize the financial burden on all of the smaller manufacturers. As a result, only one small-entity engine manufacturer would be impacted by more than one percent of sales, and even this percentage could likely be reduced if the manufacturer were to take advantage of the small volume engine family flexibility.

8.3 Impact on Equipment Manufacturers

8.3.1 Number of Small Manufacturers

With few exceptions, handheld equipment manufacturers are typically also the engine manufacturers. The first exception to this rule consists of the small auger manufacturers. These manufacturers rely upon the engines being produced in the marketplace. Since publication of the NPRM, six such auger manufacturers have been brought to the agency's attention. The other exception is handheld equipment made by nonhandheld manufacturers. EPA has identified an additional six manufacturers, including four lawn and garden and two paving equipment producers. Total production for these manufacturers is on the order of 65,000 units per year, out of a total handheld production of roughly ten million pieces of equipment. Production for these 12 manufacturers is limited to

Class IV and V equipment, with two of them manufacturing only Class IV equipment, seven manufacturing only Class V equipment, and the remainder manufacturing both Class IV and V. In addition to the twelve small businesses, EPA has also identified two equipment manufacturers which are not small entities.

8.3.2 Impact on Equipment Manufacturers

Because handheld equipment manufacturers are also often the engine manufacturers and because of the relatively low number of handheld equipment lines, EPA estimates that the impact on equipment manufacturers will be minimal. The handheld manufacturers will be afforded ample lead time by the effective dates for the proposed standards, so that equipment changes and engine changes can be phased in together. Auger manufacturers and other relatively low-volume manufacturers who do not also manufacture their own engines fear a potential lack of availability of engines. Because of their relatively low production levels, the auger manufacturers have expressed concerns that engine manufacturers would be reluctant to make the necessary investment to develop compliant engines suitable for their particular applications. Some have also expressed concerns that the power characteristics of a 4-stroke engine may not be suitable for requirements of their particular applications. However, again, EPA is providing flexibilities that should address these concerns and allow these relatively few entities to continue production of their products.

8.3.3 Possibility of Cost Passthrough

Some manufacturers have expressed concerns that OHV and other advanced technologies will necessitate price increases that will diminish the demand for their products. However, EPA believes that the need for the products will likely remain regardless of cost increases--lawns will need care, construction will need to go on, etc. Then too, across-the-board increases for SI engines will ultimately impact all equipment manufacturers equally so that no manufacturer should gain a substantial competitive advantage. Individual small business equipment manufacturers have informed EPA of the likelihood they would pass most, if not all, additional costs on to consumers. Many of these small business equipment manufacturers appear to cater to niche markets, which provides a better opportunity for partial or even full cost passthrough.

8.4 Estimation of Impacts on Small-Volume Equipment Manufacturers:

8.4.1 Base Case--No Flexibilities

Under the proposed standards, EPA calculated only the sales impact on the handheld engine/equipment manufacturers that were classified as small business entities. Cost estimates were calculated per equipment model for each manufacturer. Each equipment model is assumed to correspond to an application with a specific horsepower rating. To calculate an annualized cost of compliance for each manufacturer, the fixed costs per model were multiplied by the number of equipment models produced by that manufacturer. The fixed costs for each model were then annualized using a nine percent annual cost of capital over a ten year period. The variable costs per unit were multiplied by the number of units produced annually, yielding total annual variable costs. These costs were then added to the annualized fixed costs to calculate the total annualized cost per manufacturer. The results were compared to total value of sales for the manufacturer to determine the costs as a percentage of sales. The base case depicts a worst-case scenario, in which none of the small-business equipment manufacturers take advantage of the flexibilities provided for small volume manufacturers or small volume equipment lines.

Because there were relatively few manufacturers identified, and because of their low number of models, the analysis concluded that the proposed standards would pose a minimal impact on small business . An analysis of the

D&B data for the twelve equipment-only manufacturers indicates that half the equipment manufacturers would be impacted by less than one percent of sales, four would be impacted by between one and three percent of sales, and only two would incur costs amounting to more than three percent of annual sales. However, the possibility remains that engine manufacturers may cease to produce engines suitable for the low-volume auger and other applications. EPA is therefore providing flexibilities for small equipment manufacturers and model lines in an attempt to avoid this possibility.

8.4.2 Flexibilities Case

EPA is proposing a number of small-volume flexibilities which can ease the burden of compliance on these smallest entities. There are two major small-volume flexibilities operating to benefit small equipment manufacturers:

(1) Small volume equipment manufacturers are defined as those manufacturers who produce less than 25,000 units per year for handheld applications. Small volume equipment manufacturers could use Phase 1 engines for 3 years beyond last date of standards phase-in. Engine manufacturers would be allowed to continue production of the necessary engines to satisfy this demand.

(2) Small volume equipment models are defined as model lines consisting of less than 2,500 units for handheld model lines. Small volume equipment models can use Phase 1 engines throughout the entire Phase 2 period if no suitable Phase 2 engine is available. Again, engine manufacturers will be allowed to continue production of the engines necessary to satisfy the demand.

All but one of the 12 small equipment manufacturers will be able to take advantage of the small volume manufacturer flexibilities. However, the one small entity equipment manufacturer which would not be able to utilize this flexibility would be impacted less than one percent of sales by the proposed standards. The 11 other manufacturers would also qualify for the small equipment model flexibility for all but one of their product lines. Unfortunately, the small volume equipment model flexibility would also not help the one firm that did not qualify as a small volume manufacturer, but the impact on that producer is relatively minimal, even without the flexibilities. The flexibilities should help address the concerns expressed by the handheld auger manufacturers about the potential lack of engines. The equipment flexibility would at least enable continued production of the engines that are currently utilized for these applications. The recent advances in 2-stroke technology may also preclude the necessity of conversion to 4-stroke engines, which would also address many of their concerns.

8.5 Conclusions

Analysis of the current data shows that the majority of engine and equipment manufacturing firms (representing more than 90 percent of handheld production) are not small business entities. Of those who are, only three small engine manufacturers and six small equipment manufacturer would be impacted by more than one percent of sales, even without taking advantage of the flexibilities provided. If the small manufacturers do take advantage of the flexibilities offered, only one engine producer would be affected by more than 1 percent of sales, and equipment manufacturers would be affected to an even lesser degree. Moreover, there are other mitigating factors which enter into the cost equation. The inclusion of additional flexibilities, which will benefit both small engine and equipment businesses, will further reduce impacts. For example, it is possible for some of the companies to be in a state of poor financial health, which would further increase the compliance burden. EPA is therefore proposing to allow handheld manufacturers to use the hardship provision that was recently adopted in the Phase 2 small nonhandheld SI final rulemaking, which provides additional relief to companies undergoing severe financial distress.

8.6 Outreach Activities

In addition to the comments received on the original NPRM, EPA has made other outreach efforts. A number of small businesses were contacted to determine the impact of the more stringent standards for handheld engines. In addition, EPA has been in almost constant contact with engine producers, including the small entities, at their own request or at the request of trade associations. Many of these firms who have provided input to the process believe that sufficient lead time can alleviate some of the problems associated with a transition to OHV or other advanced technology. Additional lead time allows for a more orderly transition to this advanced technology when other changes are made.

Chapter 8 References

1. "Small Business Impact Analysis of New Emission Standards for Small Spark-Ignition Nonroad Engines and Equipment," prepared for EPA by ICF Incorporated under EPA Contract 68-C5-0010, August 1998, available in Docket A-96-55.

2. "Cost Study for Small Engine Emission Regulations," prepared for EPA by ICF Incorporated under EPA Contract 68-C5-0010, October, 1996, available in Docket A-96-55.

Chapter 9: Useful Life and Flexibility Supporting Data

9.1 Information on Useful Life

This Chapter contains information used by the Agency in the development of the proposed useful life categories for Phase 2 small engines for handheld (Classes III-V), Class I-A and Class I-B.

During the development of the Phase 2 program, and during the development of the Phase 1 regulation, EPA was aware that the nonroad SI category of engines and equipment was comprised of a wide variety of equipment with a wide range of usage patterns. Handheld engines are designed for many different types of applications, with each application having specific design criteria. Within each application are a number of markets with different target life expectancies. The most obvious example of these differences is the distinction between commercial (or professional) operators and residential (or home) operators. In general, commercial operators expect to accumulate high numbers of hours on equipment on an annual basis, such as commercial lawn-care companies or rental companies, while a residential operator expects to accumulate a relatively low number of hours on an annual basis, such as a residential chain saw owner. Several organizations have investigated the issues related to average life and annual use of equipment powered by small SI engines, including industry organizations, CARB, and the EPA. A brief summary of several of these reports is presented in the remainder of this Chapter.

9.1.1 Handheld Useful Life Estimates from PPEMA

In 1990 the Portable Power Equipment Manufacturers Association (PP EMA) contracted for a report which contained estimates on useful life periods for 2-stroke powered handheld equipment.(Ref. 1) A summary of the information contained in the report on 2-stroke powered handheld equipment usage is presented in Table 9-01.

Table 9-01
Summary of Information on Useful Life
Available from Heiden Associates Report, July, 1990
(Con. = consumer user, Prof. = professional user)

Equipment Type	Con. Average Annual Use (hours)	Prof. Average Annual Use (hours)	Con. User Expected Life Estimates (years)	Prof. User Expected Life Estimates (years)	% of Equipment Purchased by Prof. Users	Con. User Expected Life Estimates (hours)	Prof. User Expected Life Estimates (hours)
Chain saws	7	405	8	1	25%	56	405
Trimmers & Brushcutters	10	170	6	1.5	16%	60	255
Hand Blowers	9	197	6.67	2	5%	60	394
Back Blowers	12	293	6.67	1.83	95%	80	536
Cut Off Saws	N / A	113		2	100%	N / A	226
Hedge Trimmers	7	75	7.5	3	79%	53	225

This report clearly demonstrates the large disparity between consumer and professional use, with consumer equipment expected life estimates range from 53 to 80 hours, and professional equipment expected life estimates range from 225 to 536 hours.

9.1.2 Handheld Useful Life Estimates from CARB

In 1990, the California Air Resources Board (CARB) contracted for a report from Booz, Allen and Hamilton which included estimates of usage rates and life spans for several categories of nonroad equipment powered by small engines(Ref. 2). A summary of the information contained in the report pertaining to handheld applications is presented in Table 9-02.

Table 9-02
Summary of Information on Useful Life
Available from Booz, Allen & Hamilton Report, Nov. 1990
(Res. = residential user, Com. = commercial user)

Product Category	% of Total Sales, Home Use	% of Total Sales, Commercial Use	Res. Implied Avg. Lifespan (years)	Com. Implied Avg. Lifespan (years)	Res. Annual Hrs Use per Year	Com. Annual Hrs Use per Year	Res. Implied Avg. Lifespan (hours)	Com. Implied Avg. Lifespan (hours)
Tillers	60%	40%	7.04	5.41	18	72	127	390
Snowthrowers	90%	10%	5.41	5.41	10	60	54	325
General Utility	25%	75%	7.04	2.85	5	96	35	274
2-cyc. blowers / vacuums	85%	15%	5.21	2.85	10	170	52	485
2-cyc. edgers / trimmers	85%	15%	5.21	2.85	10	275	52	784
Chain saws	75%	25%	5.21	1.33	7	405	36	539

This report also indicates there is a large disparity in average life-span between equipment used by residential and commercial applications. Residential equipment implied average lifespan estimates range from 35 to 127 hours, and commercial equipment implied average lifespan estimates range from 274 to 784 hours.

9.1.3 Small Engine Equipment Usage Estimates used by EPA

The Agency has also developed estimates related to average annual use and equipment survival, many of these estimates are based on the usage information in the previously cited reports. These estimates were presented in the Small Engine Phase 1 Regulatory Support Document.(Ref. 3) The Phase 1 RSD includes Agency estimates of: average annual sales by equipment type, percentage splits between residential and consumer equipment, average annual use by equipment, B-50 (number of years after which 50 percent of the equipment have failed), and sales splits by equipment between each of the five engine Classes. Figures 9-01 through 9-03 are a series of bar graphs summarizing the Agency's information regarding engine Classes and hours of use.

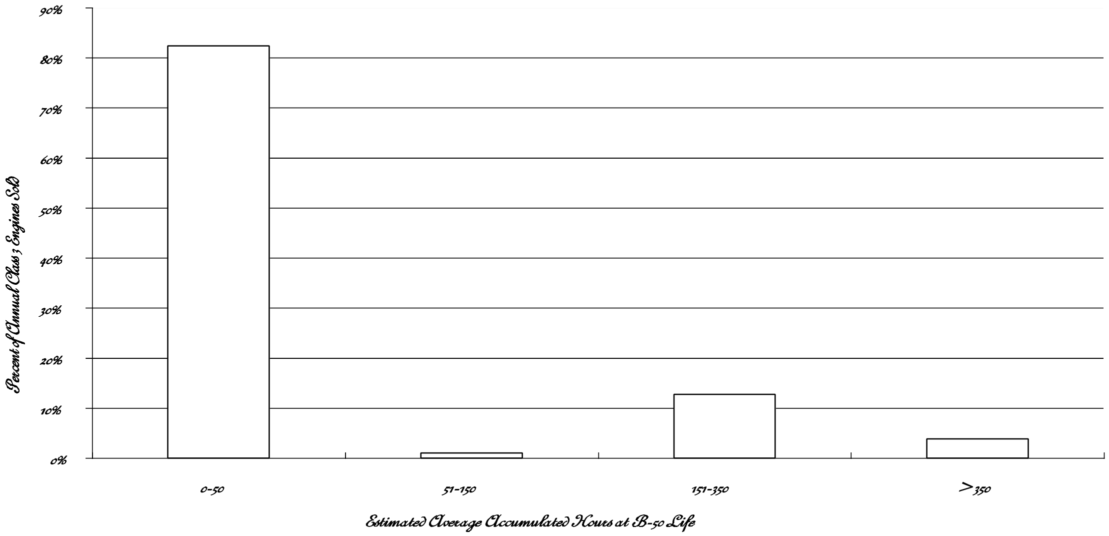

Figure 9-01: Summay of EPA Class 3 Engines Useful Life Estimates

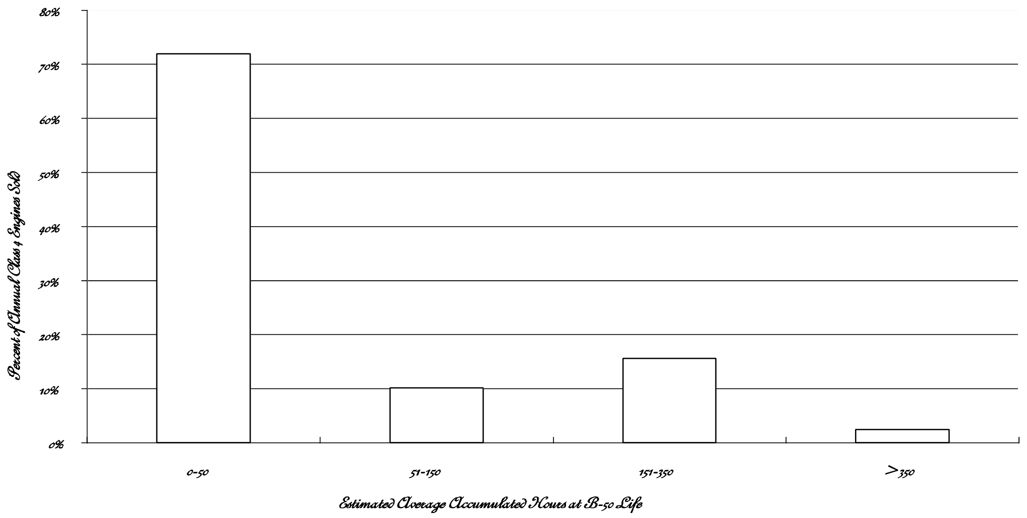

Figure 9-02: Summary of EPA Class 4 Engines Useful Life Estimates

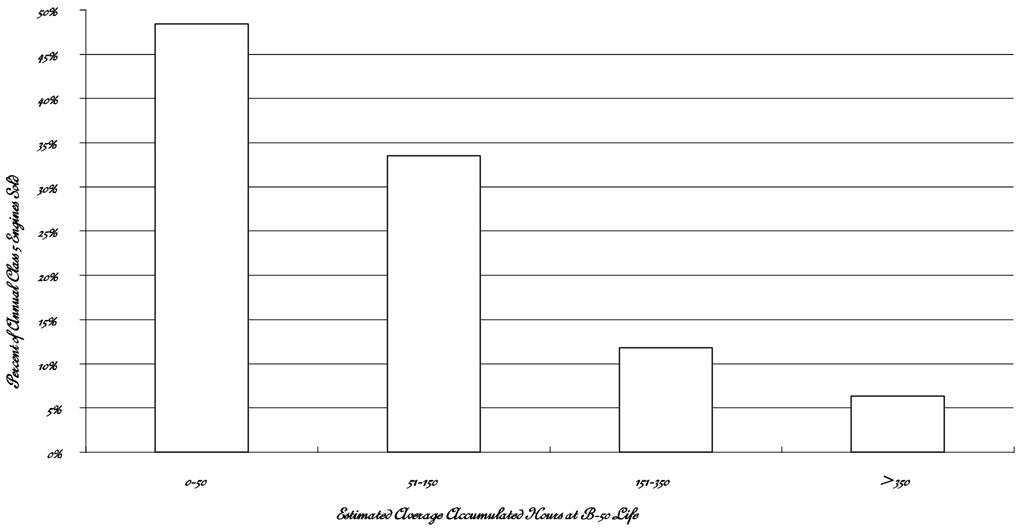

Figure 9-03: Summay of EPA Class 5 Engines Useful Life Estimates

Figures 9-01 thru 9-03 make it clear that small engines can accumulate vastly different hours of use over the life of the equipment. Manufacturers are able to design and build engines for various design lives which fit the type of equipment the engine is likely to be produced for.

9.1.4 Phase 2 Useful Life Categories

EPA is proposing several useful life categories for handheld engines (Classes III-V), presented in Table 9-03. Based on the data presented in Sections 9.1.1 thru 9.1.4 the Agency believes these useful lives are appropriate for regulatory purposes.

Table 9-03
Regulatory Useful Life Values for Small SI Handheld Engines (Classes III-V)

Category	C	B	A
Useful Life (hours)	50	125	300

The Agency believes multiple useful life categories are appropriate considering the wide range of useful life values for small SI engines. At the same time, the Agency would like to keep the number of useful life categories small to avoid confusion among consumers. The Agency believes the three categories for handheld engines fulfils the goal of having a small number of useful life categories, and at the same time, adequately covering the useful lives experienced by engines in actual use.

For Class I-A engine families, the useful lives are the same as for Classes III-V since Class I-A families are just an extension of these engines to nonhandheld applications. Class I-B engine families will utilize Class I useful life categories (125, 250, 500) since the majority of engine families that will certify to this Class are already certified to Class I Phase 1 standards.

9.2 Background for Choice of Small Volume and Small Family Cutoffs

The Preamble for this rulemaking contains a number of flexibilities for small volume engine and equipment manufacturers as well as small volume engine families and equipment models, see Table 9-04 at the end of this section. This section describes the methodology utilized to develop these estimates. The main sources for this analysis include the September 1998 EPA Phase 1 certification database (engine/equipment manufacturers) and Power Systems Research 1996 OE LINK database (independent equipment manufacturers) along with the results from EPA's work to analyze the impact on small businesses which can be found in Chapter 8.

9.2.1 Small Volume Handheld Engine Manufacturers

The work performed to determine the impacts on small businesses, as described in Chapter 8 of this RIA, utilized the SBA definition of 1000 employees as a cutoff for small volume engine manufacturers. Application of this definition to the range of engine manufacturers in this industry resulted in identification of 6 small engine manufacturers. Only 5 of these companies were able to be analyzed, since both financial and estimated production information are necessary for the analysis. An overview of the companies showed that they varied greatly in income and production volumes. Two of the five companies were clearly small with low number of employees and annual revenue. Due to production volume and number of engine families produced, the sixth company could reasonably be assumed to be small as well. However, three of the companies produced 75,000 to 700,000 engines and had very high annual incomes. The high annual income and the high volume of engine production of some companies raised doubt regarding the use of the SBA definition for developing small volume manufacturer cutoffs. EPA therefore consulted the Phase 1 certification database for its basis of a new definition of small volume engine manufacturer.

EPA reviewed the September 1998 Phase 1 certification database for the range of engine manufacturers and their estimated annual production. EPA observed that there is a range of volumes among the engine manufacturers for the handheld industry. The total projected sales numbers are seen to be less than 25,000 for 6, 25,000 -35,000 for 2 engine manufacturers and greater than 50,000 for the remaining handheld engine manufacturers. Based on this, the proposed production cutoffs selected are listed in Table 9-05.

Table 9-05
Production Cutoffs for Small Volume Engine Manufacturer

Handheld Engines	25,000 units

Application of these cutoffs to the September 1998 EPA Phase 1 database show that the handheld definition will include 14% of the companies, but only 0.3% of the total engine production.

9.2.2 Small Volume Engine Family

Data utilized to determine small engine families for the handheld sections of this industry were from the EPA Phase I certification database.

The proposed small engine family cutoff for handheld engines is presented in Table 9-06. A value of 5,000 is proposed for handheld engine families, which is the same as nonhandheld, as requested by EMA and PPEMA in comments to the January 1998 NPRM.

Table 9-06
Small Engine Family Definition

Handheld Engines	5,000

The result is that approximately 45% of total number of engine families in the handheld industry would be considered small engine families. While this may seem like a large number of families, when one compares the number of engines represented by these families and the total number of engines, only 1.74% of the annual production of small engines will be included in this definition.

Overall, the total engine production that will fall under the two definitions of small engine family and small engine manufacturer amounts to only 1.77% of the total production for the handheld industry as a whole.

9.2.3 Small Volume Equipment Manufacturer

The 1996 Power Systems Research EO LINK database and information from various equipment manufacturer associations and equipment manufacturer websites were utilized to determine the cutoffs for small volume equipment manufacturers (NOTE: This flexibility applies for equipment manufacturers that do not make their own engines). Table 9-07 contains the proposed cut off for small volume equipment manufacturers.

For handheld equipment manufacturers, the proposed cutoff is 25,000 units, which is the same as the small volume engine manufacturer. The basis for this proposal is that a review of the small volume equipment manufacturers (of which there are only 11), show this to be a reasonable cutoff in order to provide manufacturers the flexibilities to change their production to use Phase 2 certified engines. This provision affects 79% of the equipment manufacturers identified in the PSR database or elsewhere as producing equipment with handheld engines. However, these small-volume equipment companies utilize only about

0.3% of the total number of engines produced each year.

Table 9-07
Small Volume Equipment Manufacturer Cutoff

Handheld Units	25,000

9.2.4 Small Volume Equipment Model

The proposed cutoff for small volume handheld equipment model (in which the equipment manufacturer does not make engines as well) is presented in Table 9-08 and is 2,500 units/model. This flexibility would affect only one, or possibly two, manufacturers that would not also be considered small volume equipment manufacturers. Production data were not available for one large multinational firm which markets on five continents, advertising itself as one of the largest lawn and garden equipment manufacturers in Europe, and it will thus be considered a large volume equipment manufacturer. However, even if all eight of this manufacturer’s product lines were to qualify for small model flexibilities, the resultant percentage of equipment being allowed to utilize a Phase 1 engine would be a minuscule portion of the total annual engine/equipment production.

There are a number of factors that will influence whether this definition is put to use by equipment manufacturers. These include 1) the distribution system for engines and equipment is complex and all engine families may meet the standards in order to have a nationwide engine program, 2) the inability for engine manufacturers to pick who gets a "lower price engine" over others, and 3) market pressure for a Phase 2 certified engine may result in less use of this flexibility.

Table 9-08
Small Volume Equipment Model Cutoff

Handheld Units	2,500

Table 9-04
Summary of Proposed Rulemaking Flexibilities

The table below lists the flexibilities included in the proposed rule. The flexibilities are for <u>handheld engine manufacturers and classes only</u> unless otherwise specified. Also, the equipment manufacturer flexibilities are for those independent equipment manufacturers who do not make engines for their own equipment.

Sector	Cutoff	Flexibility
Small Volume Handheld Engine Manufacturer	25,000	1. Allowed to be "Phase 1" engines until 3 years after Phase 2 standards fully implemented. The engines will be excluded from ABT until they are certified. The dates are: Classes III-IV 2009 MY, Class V 2011, MY. 2. Can certify using assigned deterioration factors. 3. Can opt out of PLT; SEA still applicable.
Small Volume Engine Manufacturer for Classes IA and IB	10,000	The manufacturer may elect to not participate in the PLT program, however, the SEA program would still be applicable.
Small Volume Handheld Engine Family	5,000	(same as small volume engine manufacturer)
Small Volume Engine Family for Classes IA and IB	5,000	The manufacturer may elect to not participate in the PLT program, however, the SEA program would still be applicable.

Sector	Cutoff	Flexibility
Small Volume Handheld Equipment Manufacturer	25,000	Continue using Phase 1 compliant engines through the third year after the last applicable phase-in date of the final Phase 2 standards for that engine class if the equipment manufacturer was unable to find a suitable Phase 2 engine before then. (Classes III-IV 2009MY, Class V 2011MY)
Small Volume Handheld Equipment Model	2,500	May continue to use Phase 1 compliant engines throughout the time period the Phase 2 regulation is in effect if no suitable Phase 2 engine was available and the equipment was in production at the time these Phase 2 rules were adopted. If the equipment is "significantly modified" then this exemption would end, since design accommodations could be made during such a modification to accept an engine meeting Phase 2 standards.
Any Equipment Manufacturer	Any	Any equipment manufacturer, regardless of size, for any of its applications, regardless of size, to continue using a Phase 1 engine for up to one more year beyond the last phase-in of the final standard for that engine class if the requirement to otherwise use a Phase 2 compliant engine would cause substantial financial hardship.

Chapter 9 References

1. "A 1989 California Baseline Emissions Inventory for Total Hydrocarbon & Carbon Monoxide Emissions from Portable Two-Stroke Power Equipment", prepared by Heiden Associates, Inc, for the Portable Power Equipment Manufacturers Association, July 24, 1990. This report is available in EPA Air Docket A-96-55, Docket Item # II-D-14.

2. "Utility Engine Emission Report", prepared by Booz, Allen & Hamilton Inc., for the California Air Resources Board, November 20, 1990. This report is available in EPA Air Docket A-93-25, Docket Item # II-I-02.

3. "Regulatory Support Document, Control of Air Pollution, Emission Standards for New Nonroad Spark-Ignition Engines at or Below 19 kiloWatts" US EPA, May 1995, EPA Air Docket A-93-25, Docket Item # V-B-01.

APPENDIX A

APPENDIX A: INDUSTRY CHARACTERIZATION

This Appendix discusses the structure of the industries producing engines and equipment affected by this SNPRM. The industry characterization presented here is taken from a report prepared under a contract work assignment for EPA by Jack Faucett Associates.(Ref. 1) The purpose of the work assignment was to prepare a report describing and analyzing the market structure, conduct, and performance of the small nonroad engine and equipment industry and to assess the technologies represented by the most common engines and equipment. The following descriptions are excerpted from that report. Some sections which are excerpted are specific to the Lawn and Garden Equipment Standard Industrial Code (SIC) 3524, although 11 SIC code categories were analyzed in the report. The reason this section is focusing on the lawn and garden equipment category is that most of the engines and equipment covered by this regulation are in that category. (Note that this summary is from the time of the Jack Faucett Associates report (December 1992) and has not been updated. Most information is still relevant, however company specific information is outdated.)

> [The small nonroad engine market is best described as a chain of industries that: convert raw materials into components, engines, and equipment; distribute the final product to end users; and, provide service and parts as required. The establishment of regulation or alternative-market based regulatory approaches will impact this chain of industries in a variety of ways. The structure

of this chain, and the characteristics of the industries that comprise it, will influence how successful alternative control strategies will be in practice.

...

Figure 1 provides a schematic of the relationships and flow of goods for engine manufacturers. To begin the process, raw materials and components are purchased from suppliers. Necessary raw materials include the steel and aluminum required to manufacture engine parts. The amounts and types of purchased components will vary from one manufacturer to another. Some engine manufacturers make their own parts, others purchase components. Die-cast molds are used to forge parts. The finished parts and components are assembled into engines on an assembly line.

Complete engines are sent to one of three places: equipment manufacturers, distributors, or export markets. A great deal of engines are sold directly to equipment manufacturers. In cases where engine manufacturers are vertically integrated, these sales would be recorded as intra-company transfers. Direct sales to equipment manufacturers is particularly common for high volume consumer equipment and for technically demanding equipment for the commercial market. The large volume engine manufacturers such as Briggs & Stratton and Tecumseh sell directly to mass merchandiser equipment manufacturers such as Murray Ohio Manufacturing and American Yard Products. Price and economies of scale[47] are the primary factors of competition for engine sales to mass merchandisers. For direct sales to equipment manufacturers producing mid-range and premium priced equipment, engineering and design cooperation is essential. In these cases, the engine manufacturers also work closely with the equipment manufacturers to develop superior products.

For smaller equipment manufacturers, or for some of the cases where there is no need for technical cooperation, it is usually not cost-effective for the engine manufacturer to sell engines directly to the equipment manufacturer. In those cases, engine manufacturers often ship engines to independent wholesale distributors. As independent businesses, these distributors carry engines from multiple manufacturers. The distributors then sell the engines to original equipment manufacturers (OEM’s) to be installed as product components. Distributors also sell "loose" engines as replacement parts. Large-scale end-users and dealers/retailers who provide service on used equipment are the most frequent purchasers of replacement engines. Engines not sold to equipment manufacturers or domestic distributors are shipped as exports.

In every segment of the utility industry, equipment manufacturers must decide whether to use "two-tiered" distribution channels or to interface directly with their dealer network. In a two-tiered distribution system, an independent

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[47] An economy of scale is said to exist when larger output is associated with lower average cost.

wholesale distributor acts as an interface between the equipment manufacturers and the dealer network. Distributors add value by providing service to both the equipment manufacturers and the dealer network. Distributors remove a great deal of the inventory burden from dealers. Because dealers generally do not have the facilities or financial strength to maintain large inventories, they must frequently order parts for repair. Successful distributors can usually provide parts within 24 hours. In the absence of a distributor, parts must be shipped from the equipment manufacturers by package delivery services (such as UPS). This can take several days or more, depending on manufacturer location and the availability of the part. Furthermore, because many dealerships are small businesses, they often rely on their distributors for bookkeeping and general business support. Enhanced service provided by the distributors improves the reputation of the equipment manufacturers. Also, distributors provide market information to manufacturers because they are closer to the consumers and are often able to identify emerging trends faster than the manufacturers themselves.

Despite the added value that distributors provide for both dealers and manufacturers, they are declining in numbers and importance. This shift is generally attributed to the ever increasing price competition in the consumer marketplace. The value added by distributors must be offset by the profit margin required by the additional tier in the distribution chain. Although distributors will remain important, particularly for premium line equipment, their impact on the market is projected to decline.

The distribution system for lawn and garden equipment manufacturers is probably the most diverse and complex in the utility market. This is primarily due to the different needs of the commercial and consumer markets. The bulk of all lawn and garden unit sales go to consumer end-users.[48] However, commercial customers represent too large a market to ignore, and some equipment manufacturers and members of the distribution chain focus strictly on the commercial business. Balancing the commercial customers need for performance and service with the consumer customers need for a low price is the challenge facing manufacturers and the distribution channels they have developed.

Figure 2 provides a schematic of the relationships and flow of goods from the viewpoint of the lawn and garden equipment manufacturers. These manufacturers design and manufacture their own parts and/or purchase components. The finished parts and components are assembled into end-user equipment. Finished goods are sent to one of three places: wholesale distribution dealers or other retail establishments, or shipped for export.

Some manufacturers use a direct (i.e., one-tier rather than two-tier) distribution system, dealing directly with dealers or other retail establishments. The larger the manufacturers and the larger the retail unit, the more likely that this link will be direct. Mass merchandiser manufacturers deal directly with mass merchant and discount retail outlets. Some manufacturers deal directly with all

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[48] For example, OPEI estimates that 90% of walk behind lawnmower sales go to the residential market.

types of retail outlets. The trend towards direct distribution is expected to continue, as is the trend towards the mass merchandisers. These trends serve to keep prices low, foster price based competition, and put a squeeze on distributors and local dealers. The average service dealer makes $100,000 to $250,000 in sales per year. There are 300 dealers that bring in over $1,000,000 in revenues annually. There are also a great many dealers that have less than $100,000 annual revenues. Dealers are extremely dependent on service revenue to stay in business. Approximately 50 percent of the average dealers revenues are realized through parts and repair work.[49]

As emission requirements force small nonroad engines to be more complex, more will be expected of small engine technicians. The situation is similar to automobile dealers who must perform vehicle emission compliance work. Jeff Voelz, Marketing Director at Onan Corporation, noted that, "dealers will have to get savvy and understand that this is their future."[50] As in the automotive industry, emission control advances are likely to reduce the user's maintenance abilities and require an increase in small engine technician skills.

Although two-tier distribution is declining, it is still an important feature of the distribution network. According to a survey of its members, OPEI found that 41.4 percent of shipments were distributed through wholesale distributors in 1988. Many

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[49] North American Equipment Dealers Association.

[50] Phone conversation on June 8, 1992.

manufacturers use two-tier distribution for virtually every type of retail establishment, although distributors are generally bypassed when shipments go to mass merchandisers and discounters. Because of fierce price based competition, the pressure is on distributors to prove their ability to add value in order to maintain their volumes of business in the future.

Most manufacturers choose to focus on either the consumer or commercial market. These factors, in turn, influence their choice of distribution channels. Manufacturers that focus strictly on the consumer market, especially at lower end prices, generally retail exclusively through mass merchandisers. Manufacturers that focus strictly on the commercial market, generally rely exclusively on dealers. Mid-range manufacturers and other manufacturers that wish to compete at the commercial or top-end consumer market and the low-end consumer market face a difficult choice. It is tempting to use both mass merchandisers (for sales volume) and dealers (for value added service). However, this creates tremendous conflict within the channels, particularly for the dealers. The dealers cannot match mass merchandisers on price, and frequently end up as repair shops, merely servicing the equipment that they can no longer sell. The solution to this situation that has been most successful is to sell separate lines of products, restricting the mass merchandisers from selling the higher quality product lines. McCullough has been able to do this successfully. Toro tried to do this, but eventually withdrew from mass merchandiser outlets. Toro is now trying the mass merchandisers again with its Lawnboy subsidiary.

This discussion of lawn and garden manufacturer distribution channels primarily addresses nonhandheld equipment manufacturers, although, in general, it applies to handheld equipment manufacturers as well. There are, however, some unique facets of the handheld manufacturers distribution networks that have not been previously addressed. The major difference is that the handheld manufacturers all make their own engines. This changes the mixture of raw materials and components they purchase as well as their manufacturing and design processes. A separate engine market would not suffice for handheld manufacturers because of the size, performance, and design restrictions placed on their products by the unique end-user requirements for handheld equipment.

There are only a handful of nonhandheld equipment manufacturers that are vertically integrated. Kubota is an example of a major manufacturer of both engines and equipment.(Ref. 2)

...

The Lawn and Garden Equipment Industry (SIC 3524) accounted for 0.11 percent of GDP in 1990. ... Constant dollar shipments have increased sharply, with a 33.1 percent increase from 1984 to 1990. ... [R]oughly the same number of companies were responsible for the increased out, indicating that new firms entering the industry may not have been responsible for higher output. Value added as a percent of output for the industry in 1990 was 40.9 percent, roughly the same as the internal combustion engine industry.

This industry does not seem to be capital intensive, as assets were only 18.8 percent of output in 1990, less than the corresponding percentage for All Manufacturing Industries. ... In addition, capital turnover rates are 15.6 years, slightly above the average for All Manufacturing Industries. As a result, should regulation result in new purchases of capital, the industry may not have as much difficulty as other industries in adapting to regulatory actions.

Concentration in this industry is high, as the 8 largest companies control 71 percent of the market. These companies may have the ability to influence the price of their products. Yet the industry does not seem to have excess capacity, with a capacity utilization rate of 73 percent. This figure is slightly less than the 76 percent rate for All Manufacturing Industries. ...

...

Because the Statistics of Income Classification code relevant to the Farm Machinery and Equipment industry includes both 4-digit SIC codes 3523 and 3524, the profitability analysis for the Farm Machinery and Equipment industry also applies to the Lawn and Garden Equipment industry. For 1988, profitability for this industry seemed quite good, with the average return on equity up to 17.9 percent, a 14.1 percent increase from 1990. The average debt to asset ratio, however, is among the higher of the seven minor industries considered ... at 42 percent.

...

Constant dollar shipments are expected to grow at an annual rate of 2 percent over the next 5 years for the Lawn and Garden Equipment industry. The U.S. Industrial Outlook attributes this increase to several factors, first among them are demographic changes in the U.S. population. In particular, the fastest growing age group, 44-54, will be near their maximum earning potential, which should result in larger expenditures on lawn and garden equipment. The report also notes that many of these consumers will be more inclined to upgrade their current properties, which may entail landscaping. The removal of trade barriers in Mexico and Canada as a result of the North American Free Trade Agreement (NAFTA) should give companies in the three North American countries the opportunity to expand their exports. In addition, the report mentions that possible environmental standards may have an impact on sales, but the report does not give a clear indication of whether or not these regulations will cause sales to increase or decrease.(Ref. 3)

...

[M]any of the eleven 4-digit SIC industries encompassing the small nonroad engine and equipment industry are characterized by significant value added, fairly high concentration, growth in the value of shipments, capital intense production processes, high capital turnover, and relatively efficient capacity utilization. These basic industry trends determine the competitive nature of the industry and condition the interactions of the firms that form these industries with suppliers, consumers and each other.(Ref. 4)

[The competitive features of the small nonroad engine and equipment industry have been reviewed. These features include: channels of product distribution, the levels of vertical and horizontal integration across engine and equipment manufacturers supplying the nonroad engine and equipment industry, the types and extent of barriers to entry that may exist in this industry, the degree of market power inherent in the nonroad engine and equipment industry at various levels of producer interactions, the availability and importance of substitute power sources for these engines, the global competitive position of U.S. firms in this industry, and characteristics of end-users which drive the demand for the various products that are sold in the small nonroad equipment industry. Such a comprehensive description of this industry's competitive features has revealed various interesting results which should be summarized.

First, the level of vertical integration in the small nonroad engine and equipment industry appears to be rather small. Where present, vertical integration is concentrated in three areas of the industry: foreign lawn and garden engine and equipment manufacturers, foreign recreational engine and equipment manufacturers, and handheld lawn and garden engine and equipment manufacturers. For example, Honda produces both the engine and equipment components of their lawn and garden products... In fact, most of the vertically integrated companies are foreign companies.

Horizontal integration, on the other hand, is common among engine manufacturers in the small nonroad engine and equipment industry. This follows directly from the fact that a single engine design is often used in many small nonroad equipment applications. ...[T]ecumseh and Briggs & Stratton engines, for example, are employed by various types of equipment including lawn and garden equipment, light commercial and industrial equipment, light agricultural equipment, and others.

Second, advertising and product differentiation, economies of scale, and large capital requirements appear to be the only forms of barriers to entry that <u>may</u> characterize the small nonroad engine and equipment industry. However, the effectiveness of these phenomena is difficult to assess. Nevertheless, advertising plays an important role in the lawn and garden equipment industry, as shown by its relatively high advertising intensity ratio. Similarly, product differentiation is important in this market as evidenced by the large number of brands and product models that are offered for different equipment types, such as lawnmowers or chainsaws...

Economies of scale and large capital requirements, on the other hand, are likely to be more important at the engine manufacturing level of the industry, since this level is capital intensive and characterized by few dominant sellers. It should also be noted that patents may play an important role in deterring new entry as a result of Section 308 of the Clean Air Act. Ryobi, for example, may clearly have a competitive advantage if its new 4-stroke CleanAir Engine is protected through patent.

...[O]ne general characteristic of the industries that comprise the small nonroad engine and equipment industry is high levels of seller concentration. Empirically, high seller concentration has been shown to perpetuate product pricing that is above the marginal cost of the products production.(Ref. 5) ...[R]esults that are characterized by this pricing outcome are economically inefficient, and display the market power, of at least the market leaders, in the industry. However, although the small nonroad engine and equipment industry is generally characterized by seller concentration, ...the various relationships between the economic agents operating in this industry are not characterized by significant levels of market power. Much of the reasoning behind this conclusion centers on the concept of contestable markets... The fact that the small nonroad engine and equipment industry is not characterized by market power implies that if regulatory actions increase the production costs of the firms producing in this industry, then these incremental costs will likely be passed on to consumers, or end-users, in the form of higher prices. Moreover, the likelihood that market power is not prevalent in the small nonroad engine and equipment industry implies that economic profits are not being accrued in the long run. This in turn suggests that entry into the market is relatively free. Although some aspects of barriers to entry may exist (such as product differentiation, advertising, and economies of scale), their effectiveness at deterring entry is not necessarily evident.

Fourth, the prevalence of substitute power sources and equipment that displace equipment powered by internal combustion engines is most evident in the lawn and garden equipment market where electrically powered machines have been common for many years. However, the sale of electrified lawn and garden equipment is hampered by various factors. For example, the long extension cords necessary for the operation of electrified equipment are cumbersome, while electrified lawn and garden equipment are generally not a viable option for commercial users. However, use of battery packs could potentially resolve some of the detrimental user oriented externalities associated with electrically powered lawn and garden equipment (Ref. 6).

Appendix A References

1. Jack Faucett Associates, *Small Nonroad Engine and Equipment Industry Study*, JACKFAU-92-413-14, December 1992

2. ibid, pages 68-76

3. ibid, pages 57-58

4. ibid, p. 67

5. Curry, B., George, K.D., *Industrial Concentration: A Survey*, The Journal of Industrial Economics, March 1983

6. Jack Faucett Associates, *Small Nonroad Engine and Equipment Industry Study*, JACKFAU-92-413-14, December 1992, p. 123-126.

NOTE: Graphs not included in this electronic version

APPENDIX B

Appendix B: Manufacturer and Product Summary

B.1. Introduction

This appendix summarizes information on the equipment related to the category of engines regulated, nonroad 0-19 kilowatt handheld spark-ignited engines. This appendix summarizes the engine manufacturers and their products, the technology used on these engines, and estimates the amount of these engines consumed in the United States.

B.2. Engine Manufacturer Summary

There are a wide variety of engine manufacturers producing engine products which will be regulated. Data on the manufacturers and their products is provided from EPA's Phase 1 certification database[51].

B.2.1. Listing of Known Engine Manufacturers

EPA has generated a listing of engine manufacturers from the September 1998 EPA Phase 1 certification database. It appears that there are 22 manufacturers which produce 2-stroke engine families and three manufacturers which produce 4-stroke engine families.

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[51] All engine models for production in the 1997 model year were to be certified by September 1, 1997. The only exception are those models that are exempt from CARB's Tier 1 program (Class V engines) which have until January 1, 1998.

B.2.2. Listing of Known Engine Models per Manufacturer

The EPA Phase 1 database contains the most extensive listing of information at the engine model level. The data in this section is excerpted from this database. Presented in Table B-01 are the number of engine models per manufacturer and the estimated number of engine models in each standard category.

B.2.2.1. Number of Engine Models- Table B-01 shows that there are 186 engine models in Classes III-V. There are nine manufacturers of handheld engines who produce less than five engine models. The more engine models a manufacturer produces does not correlate to overall more engine sales. Some engine manufacturers are specialized and serve a number of specialty markets.

B.2.2.2. Engine Family and Emissions Per Engine Family Per Class – Tables B-02 through B-04 contain information per engine family per manufacturer on engine family, new engine emissions (HC, NOx, CO), emission control technology, major applications and displacement.

Since the proposed Phase 2 regulation is an in-use set of standards, the new engine values from the September 1998 Phase 1 certification database have been deteriorated to compare to the new engine standard. Deterioration factors were taken from data submitted by industry and EPA's own analysis. Table B-05 lists the deterioration factors applied to the corresponding engine families. EPA requests comment on the accuracy of the information presented in all tables in this Appendix.

Table B-05
Deterioration Factors

Engine Class	III	IV	V
	HC / NOx	HC+NOx or HC / NOx	HC / NOx
4-Stroke OHV	--	1.5	--
2-Stroke	1.1 / 1.0	1.1 / 1.0	1.1 / 1.0
2-Stroke w/ Catalyst	--	1.3	--

B.3. Estimate of Historical and Future Equipment Consumption (Sales)

Information on the estimate of historical sales is summarized in this section. Historical data came from EPA's analysis of the information from the PSR database as well as information from Outdoor Power Equipment Institute (OPEI), the Portable Power Equipment Manufacturers Association (PPEMA), and a study done for the California Air Resources Board by Booz, Allen, Hamilton (BAH). Data presented in this section show the estimates of historical consumption from these sources. This information was used in EPA's check of the 1996 population estimates being used in the NONROAD model. The information on future equipment consumption is described in chapter 6.

Table B-01

Engine Manufacturers and Engine Families Per Class and Engine Type

September 1998 EPA Phase 1 Certification Database

MANUFACTURER	HANDHELD					TOTAL
	III 2-S	IV 4-S	IV 2-S	V 2-S	V 4-S	
Emak s.p.a.			4	4		8
Fuji Heavy Industries, Ltd.			1	4	1	6
Fuji Robin Industries	1		2	1		4
Honda		2			2	4
Husqvarna AB			11	16		27
Ishikawajima Shibaura Machinery Co.			4			4
John Deere Consumer Products, Inc.	1		8	2		11
Kawasaki	1		7			8
Kioritz			8			8
Kioritz-Echo			10			10
Komatsu-Zenoah			7	1		8
Makita USA, Inc.			7	8		15
Maruyama US Inc.			7			7
Mitsubishi Engine North America, Inc or Mitsubishi Motors Corporation			2			2
Poulan	3		10	1		14
Ryobi		1	3			4
Shin-Daiwa Kogyo Co. Ltd			13			13
Solo Incorporated			1	1		2
Stihl			12	11		23
Tanaka Kogyo Co. Ltd	2		1			3
Tecumseh			1	3		4
Wacker-Werke GmbH&Co KG.				1		1
TOTALS	8	3	119	53		186

NOTE: There may be a few double counted models if families have been certified in more than one model year to date. Some duplicates have been removed. Also, note that this list contains engine families that are snowblower applications which only have to meet the CO standard and therefore are not included in the analysis for this HC+NOx focused rulemaking. There also exist several engine families for lawnmowers which will be phased out in the early 2000's.

APPENDIX C

APPENDIX D

(Reserved)

APPENDIX E

APPENDIX F