



Fire Apparatus Manufacturer's Association

# Fire Apparatus Duty Cycle White Paper

FAMA Technical Committee  
Chassis Subcommittee

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Added Statistical Data for Chief's Survey Results

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## Purpose

This paper has been created by the Chassis Technical Committee of the Fire Apparatus Manufacturer's Association for the follow purpose:

- Provide guidance to fire apparatus manufacturers on the life expectancy and use profile for major types of fire apparatus.
- Estimate the average engine duty cycle in a fire apparatus.
- Provide a tool for engine manufacturers to use when estimating the impact of fire apparatus engine emissions.

## Methods

- Survey of Fire Chiefs
- Instrumentation of selected vehicles to log data on use profiles
- Engine Data Collection

## Definition of Terms

Urban	Area served by the fire department is obviously metropolitan and consists of high-density housing, industrial, or retail structures.
Suburban	Area served is mainly single family housing, light retail or light industry. Could be outskirts of metropolitan areas or smaller communities.
Rural	Area served is small towns and low density population regions that would include significant distances between the station and the structures being protected.

## PART I - Survey of Fire Chiefs

### Description

In January 2004, *Pierce Manufacturing* conducted an independent quantitative research survey through *Added Value Inc.* that was designed to provide information on the usage patterns for fire apparatus. Among the information sought through this survey were the following topics:

- Department demographics
- Number of apparatus by type
- Average number of runs per week
- Average length of run
- Average miles driven per year

The methodology for the research survey was as follows:

- A one-page questionnaire was developed consisting of 15 closed-end questions.
- A list of 1200 fire chiefs representing a cross-section of the U.S. was created.
- A code number was printed at the bottom of each questionnaire to allow *Added Value Inc.* to track responses.
- All Questionnaires were mailed with a postage-paid return envelope, and a cover letter from *Pierce Manufacturing*.
- The cutoff date for the survey receipt was February 23, 2004.

The response rate for the survey was 30%

### Respondent Profile

Respondents who were fire chiefs or assistant fire chiefs 69%

#### Type of Department

Career fire departments	30%
Volunteer departments	45%
Combination career/volunteer	25%

#### Population Served

50,000 or less	82%
50,000 to 100,000	11%
100,000 or more	7%

#### Demographics Served

Urban	25%
Suburban	46%
Rural	48%

Topography of Region Served

Relatively Flat	58%
Hilly	36%
Mountainous	14%

**Average Apparatus Per Department by Type**

Apparatus in service per department

Pumper	5.8
Aerial	1.5
Rescue	2.5

Chassis Type (newest apparatus)

	<u>Custom</u>	<u>Commercial</u>
Pumper	77%	23%
Aerial	93%	7%
Rescue	46%	53%

## Life Expectancy - All

### Years Expected in Active Service

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	17	5	40	5.67	8.5	26.5
Newest Aerial	19	7	30	5.58	9.5	29.0
Newest Rescue	15	4	30	6.39	4.5	27.5

### Years Expected in Reserve Service

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	12	1	40	8.85	2.5	29.0
Newest Aerial	10	1	40	9.16	2.5	27.5
Newest Rescue	9	1	35	8.17	1.5	27.5

## Annual Apparatus Usage - All

### Miles

#### Total Miles Driven in last 12 months

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	4,501	25	35,000	5,151	175	14,500
Newest Aerial	3,663	50	20,000	4,042	125	11,000
Newest Rescue	4,898	15	35,000	7,280	175	22,250

### Engine Hours

#### Total Engine Hours in last 12 months

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	655	10	8,000	1,062	27.5	1,997
Newest Aerial	413	2	2,003	409	18.0	1,266
Newest Rescue	705	5	4,400	972	24.5	2,850

#### Total Engine Hours per Week

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	12.6	0.19	153.85	20.42	0.53	38.41
Newest Aerial	7.9	0.04	38.52	7.87	0.34	24.35
Newest Rescue	13.5	0.10	84.62	18.70	0.47	54.71

## Idle Time

### Hours at Idle Per Week

	<u>Ave</u>
Newest Rescue	10
Newest Pumper	9
Newest Aerial	7

## Runs

### Runs per Week

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	15	0.25	100	19.42	0.63	61
Newest Aerial	10	0.25	60	12.34	0.75	37
Newest Rescue	16	0.25	100	21.02	0.63	65

### Runs per Year

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	780	13	5,200	1,010	31.5	3224
Newest Aerial	520	13	3,120	642	39.0	1924
Newest Rescue	832	13	5,200	1,093	31.5	3380

## Life Expectancy by Demographics of Population Served

### Active Service

#### Years Expected in Active Service – Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	15	6	30	5.33	7.5	23.5
Newest Aerial	18	7	30	6.08	9.0	29.0
Newest Rescue	13	4	30	6.99	4.5	25.0

#### Years Expected in Active Service – Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	16	5	30	5.18	9.0	23.5
Newest Aerial	19	7	30	5.27	8.5	27.5
Newest Rescue	15	4	30	6.33	4.5	27.5

#### Years Expected in Active Service – Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	18	7	30	6.35	8.5	23.5
Newest Aerial	21	7	40	5.76	9.5	29.0
Newest Rescue	16	5	30	6.12	5.5	27.5



## Reserve Service

### Years Expected in Reserve Service – Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	10	2	40	8.00	2.5	24.5
Newest Aerial	9	3	40	8.63	1.0	27.5
Newest Rescue	7	2	25	5.02	2.5	17.5

### Years Expected in Reserve Service – Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	11	1	40	8.20	1.5	27.5
Newest Aerial	10	1	40	9.05	1.5	22.5
Newest Rescue	7	1	30	7.17	1.5	17.5

### Years Expected in Reserve Service - Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	14	2	40	9.69	2.5	28.0
Newest Aerial	13	5	40	12.19	2.5	37.5
Newest Rescue	11	1	35	9.04	2.5	27.5

### Years of total service life (active plus reserve)

	<u>Urban</u>	<u>Suburban</u>	<u>Rural</u>
Newest Pumper	25	27	32
Newest Aerial	27	29	34
Newest Rescue	20	22	27

## Annual Apparatus Usage by Demographics of Population Served

### Miles

#### Total Miles Driven in last 12 Months - Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	7,629	200	35,000	7,051	400	18,750
Newest Aerial	5,083	100	17,500	4,803	150	13,750
Newest Rescue	7,534	200	35,000	9,841	350	31,250

#### Total Miles Driven in last 12 Months - Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	4,992	100	35,000	5,814	250	16,000
Newest Aerial	3,492	50	20,000	4,160	175	11,250
Newest Rescue	4,087	125	35,000	9,552	250	28,379

#### Total Miles Driven in last 12 Months - Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	3,034	25	35,000	4,540	125	7,750
Newest Aerial	2,155	100	17,500	3,549	50	8,750
Newest Rescue	3,946	30	35,000	6,388	175	15,500

## Engine Hours

### Total Engine Hours in last 12 Months - Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	873	60	8,000	1,306	80.0	1,660
Newest Aerial	540	20	1,500	436	25.0	1,341
Newest Rescue	714	30	4,000	871	50.0	1,800

### Total Engine Hours in last 12 Months - Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	572	12	3,500	595	45.0	1,520
Newest Aerial	403	10	2,003	419	18.0	1,266
Newest Rescue	648	5	3,200	750	39.5	1,875

### Total Engine Hours in last 12 Months - Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	496	10	6,000	841	18.5	1,750
Newest Aerial	279	2	1,332	352	9.0	900
Newest Rescue	745	5	4,400	1,143	10.5	3,250

### Idle Time Hours per Week – Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	11	1.0	50	11.46	0.50	37.5
Newest Aerial	8	0.5	20	6.73	0.75	18.0
Newest Rescue	13	1.0	40	13.19	0.50	27.5

### Idle Time Hours per Week – Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	10	0.5	75	11.68	0.75	28.5
Newest Aerial	7	0.5	72	9.89	0.75	17.5
Newest Rescue	9	1.0	60	9.42	0.50	27.5

### Idle Time Hours per Week – Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	6	0.5	60	8.20	0.75	17.5
Newest Aerial	5	0.5	33	6.54	0.75	12.0
Newest Rescue	8	0.5	60	9.63	0.75	22.5

## Runs

### Run Length in Miles

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Urban	4.9	2	14	3.41	1.0	6.5
Suburban	5.4	2	14	3.27	0.5	6.5
Rural	7.6	2	14	3.60	0.5	6.5

### Runs per Week – Urban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	29	1	100	27.25	1.5	78.5
Newest Aerial	13	1	48	12.15	1.0	36.0
Newest Rescue	31	1	100	27.80	0.5	88.5

### Runs per Week – Suburban

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	16	0.25	77	16.42	0.63	50.0
Newest Aerial	11	0.25	60	13.94	0.63	41.0
Newest Rescue	16	0.25	77	20.08	0.63	62.0

### Runs per Week – Rural

	<u>Ave</u>	<u>Min</u>	<u>Max</u>	<u>StDev</u>	<u>5th perc</u>	<u>95th perc</u>
Newest Pumper	8	0.25	70	16.07	0.63	30.0
Newest Aerial	5	0.25	42	8.40	0.75	18.0
Newest Rescue	11	0.25	70	15.76	0.63	44.5

## PART II - Engine Duty Cycle Extraction

### **Description**

With the advent of electronically controlled diesels, engine manufacturers have incorporated data logging capability into the Electronic Control Modules (ECM) of the engines. Both Detroit Diesel and Cummins engines have the ability to log duty cycle activity and output the results in the form of percent of time spent at varying loads and engine speeds.

The accessibility of this logged data varies between engine models, dates of manufacture and the extent to which the customers may have extracted data already. Despite these issues, the researchers were able to access data on engines from a wide spectrum of apparatus types and department demographics. The resulting data provides good insight into the manner in which the average fire apparatus is used.

Because the format of data between engine manufacturers, engine models, and ECM versions is not identical, this paper condenses the results into six buckets. The percentage of time the engine operates at various speeds is reported as follows:

Low Speed	1000 rpm or less
Medium Speed	Between 1000 rpm and 1800 rpm
High Speed	1800 rpm and above

The percent of time the engine operates at varying loads is reported as a percentage of maximum load

Low Load	0 – 10%
Medium Load	Above 10% and below 90%
High Load	90 – 100%

Time spent at negative values of torque (engine braking) is included with the low load values.

## Results

### Population of Engine ECMs Interrogated

Apparatus Type	Number of Apparatus Sampled	Average Months of Service in Extraction Record
Pumper	51	26
Aerial	21	31
Rescue	4	14
<b>Grand Total</b>	<b>76</b>	<b>26</b>

### Average Apparatus Miles Per Year by Demographic

Demographic	Apparatus Type	Average of Miles Per Year
Rural	Pumper	2,352
	Aerial	1,866
	Rescue	2,756
<b>Rural Total</b>		<b>2,347</b>
Suburban	Pumper	6,068
	Aerial	3,479
	Rescue	4,992
<b>Suburban Total</b>		<b>5,403</b>
Urban	Pumper	6,126
	Aerial	6,514
	Rescue	9,222
<b>Urban Total</b>		<b>6,478</b>
<b>Grand Total</b>		<b>5,222</b>

### Average Engine Hours Per Year By Demographic

<b>Demographic</b>	<b>Apparatus Type</b>	<b>Average of Eng Hrs</b>
Rural	Pumper	301
	Aerial	204
	Rescue	301
<b>Rural Total</b>		<b>295</b>
Suburban	Pumper	1,364
	Aerial	1,133
	Rescue	367
<b>Suburban Total</b>		<b>1,272</b>
Urban	Pumper	1,107
	Aerial	2,379
	Rescue	1,686
<b>Urban Total</b>		<b>1,681</b>
<b>Grand Total</b>		<b>1,244</b>

### Average Pump Hours Per Year By Demographic

<b>Demographic</b>	<b>Apparatus Type</b>	<b>Average of Pump Hrs</b>
Rural	Pumper	70
<b>Rural Total</b>		<b>70</b>
Suburban	Pumper	168
	Aerial	59
<b>Suburban Total</b>		<b>135</b>
Urban	Pumper	93
	Aerial	141
<b>Urban Total</b>		<b>111</b>
<b>Grand Total</b>		<b>117</b>

## Average Aerial Hours Per Year By Demographic

Demographic	Apparatus Type	Average of Aerial Hours Per Year
Rural	Aerial	63
<b>Rural Total</b>		<b>63</b>
Suburban	Aerial	64
<b>Suburban Total</b>		<b>64</b>
Urban	Aerial	72
<b>Urban Total</b>		<b>72</b>
<b>Grand Total</b>		<b>69</b>

## Time Spent at Engine Speed by Demographic

Apparatus Type	Demographic	Average Time at Low RPM	Average Time at Medium RPM	Average Time at High RPM
Pumper	Rural	63%	27%	11%
	Suburban	71%	23%	6%
	Urban	62%	32%	5%
<b>Pumper Total</b>		<b>66%</b>	<b>27%</b>	<b>7%</b>
Aerial	Rural	73%	19%	9%
	Suburban	68%	27%	5%
	Urban	73%	22%	5%
<b>Aerial Total</b>		<b>71%</b>	<b>23%</b>	<b>5%</b>
Rescue	Rural	51%	42%	7%
	Suburban	77%	17%	7%
	Urban	57%	32%	11%
<b>Rescue Total</b>		<b>61%</b>	<b>30%</b>	<b>9%</b>
<b>Grand Total</b>		<b>67%</b>	<b>26%</b>	<b>7%</b>



## Time Spent at Engine Load by Demographic

<b>Apparatus Type</b>	<b>Demographic</b>	<b>Average Time at Low Load</b>	<b>Average Time at Medium Load</b>	<b>Average Time at High Load</b>
Pumper	Rural	61%	36%	3%
	Suburban	54%	44%	3%
	Urban	73%	24%	3%
<b>Pumper Total</b>		<b>62%</b>	<b>35%</b>	<b>3%</b>
Aerial	Rural	83%	11%	6%
	Suburban	37%	58%	5%
	Urban	53%	42%	5%
<b>Aerial Total</b>		<b>50%</b>	<b>45%</b>	<b>5%</b>
Rescue	Rural	59%	39%	2%
	Suburban	78%	22%	0%
	Urban	44%	51%	5%
<b>Rescue Total</b>		<b>56%</b>	<b>41%</b>	<b>3%</b>
<b>Grand Total</b>		<b>58%</b>	<b>38%</b>	<b>3%</b>

## Average Engine Load

The Average Engine Load was determined by multiplying the percent load, by the percent time at load, then by the total HP, and summing up the results. This gives an average power load for each sample apparatus. The following chart summarizes the average power by each power rating, and finally provides an average power load for the entire sample population.

<b>Apparatus Type</b>	<b>HP</b>	<b>Average Power Load (HP)</b>
Pumper	315	44
	330	49
	350	51
	365	51
	370	68
	400	51
	430	90
	435	106
	475	111
	500	118
<b>Pumper Total</b>		<b>73</b>
Aerial	330	42
	430	81
	470	124
	500	128
<b>Aerial Total</b>		<b>104</b>
Rescue	350	32
	430	107
	500	96
<b>Rescue Total</b>		<b>86</b>
<b>Grand Total</b>		<b>82</b>

## PART III - Vehicle Data-Logging

### **Description**

Operational data was gathered by installing GPS based data logging equipment on two sample apparatus. This recording equipment was installed for a span of three weeks on each vehicle and measured the time spent accelerating, decelerating, pumping, and at idle. Engine speed was also measured. The first apparatus was a pumper located at the busiest station of a major metropolitan department. The second apparatus was located at the station of a volunteer department in a rural bedroom community.

Most of the information obtained here is duplicated with a much larger population in the Engine Duty Cycle Extraction section. The unique information obtained in this portion of the study is the percentage of time the apparatus spends accelerating or decelerating while driving, and a more detailed view of the engine speeds during pumping.

The percent of time the apparatus operates at various conditions is defined as follows:

Acceleration	+1.5 mph per second or greater
Deceleration	-1.5 mph per second or less
Steady Speed	Between +1.5 and -1.5 mph per second

### **Results**

The result of this section of the study are provided for reference purposes only. The results are not statistically significant since only two trucks are involved and only three weeks of data was collected for each vehicle. The rural apparatus only operated for 15 hours over the three week time frame and of that was only actually driving for a total of three hours. It responded to one car fire which accounts for the pumping hours.

The urban pumper probably provides a more useful profile since it accumulated 64 hours of engine-on time over the three week period. The annualized data agrees fairly well with what we might expect of a busy metropolitan station.

### **Urban Career Department Apparatus Results**

#### **Urban Pumper Percent of Time**

Acceleration	7.2 %
Deceleration	6.8 %
Steady Speed	13.6 %
Stopped with Engine Running (Pump Off)	66.6 %
Pumping	5.8 %

**Urban Pumper Hours per Year**

Acceleration	80
Deceleration	77
Steady Speed	151
Stopped with Engine Running (Pump Off)	747
Pumping	64
Total	1123

**Rural Volunteer Department Apparatus Results**

**Rural Pumper Percent of Time**

Acceleration	1.5 %
Deceleration	2.0 %
Steady Speed	18.5 %
Stopped with Engine Running (Pump Off)	61.4 %
Pumping	16.4 %

**Rural Pumper Hours per Year**

Acceleration	4
Deceleration	5
Steady Speed	46
Stopped with Engine Running (Pump Off)	152
Pumping	41
Total	247

## National Cumulative Projections for Custom Apparatus

### Data Source

FAMA reports each year on the number of apparatus sold by apparatus type (Pumper, Aerial, Rescue). This data is sent by each fire apparatus OEM to a third-party organization that tallies the results and reports the total numbers without revealing the break-down by manufacturer. This eliminates any incentive for over or under reporting, and provides what we believe to be reasonably accurate data on the fire apparatus population. These numbers are inflated because they include export sales, but they are understated by the small number of OEMs who are not members of FAMA or do not report. We believe that these reporting errors balance fairly equally and that the values reported here can be used for gross estimates with a reasonable degree of confidence.

### Results

#### All Domestic Fire Apparatus

Year	Commercial Pumper	Custom Pumper	Aerial	Rescue	Specialty	Total
1997	1425	1570	605	408	735	4743
1998	1328	1535	590	520	805	4778
1999	1561	1561	657	513	900	5192
2000	1523	1865	712	446	1016	5562
2001	1416	1755	648	447	1028	5294
2002	1321	1977	584	588	1008	5478
2003	1277	1701	537	548	1028	5091

## Custom Fire Apparatus

The number of Custom Chassis Apparatus can be estimated as follows:

100% of Custom Pumpers (as reported by FAMA )

100% of Aerial Apparatus (Nearly every Aerial is built on a custom chassis)

20% of the Rescue Apparatus

10% of the Specialty Apparatus

Year	Custom Chassis Apparatus
1997	2330
1998	2310
1999	2411
2000	2768
2001	2595
2002	2779
2003	2450

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– Roger Lackore, Pierce Manufacturing

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Cleveland Township, Indiana	Mishawaka, Indiana
Countryside, Illinois	Monona, Wisconsin
Delefield, Wisconsin	Mount Pleasant, Wisconsin
Denver, Colorado	Mukwonago, Wisconsin
DePere, Wisconsin	North Shore, Wisconsin
Dover, Pennsylvania	Plymouth, Indiana
Eagle River FPD, Colorado	Portage Township, Indiana
East Troy, Wisconsin	Racine, Wisconsin
Fivepointville, Pennsylvania	Riverside County, California
Freedom, Wisconsin	Seymour, Wisconsin
Ft Atkinson, Wisconsin	Sheboygan, Wisconsin
Glenwood Springs, Colorado	South Milwaukee, Wisconsin
Greenville, Wisconsin	Sugarland, Texas
Hand In Hand, Pennsylvania	Tualitan Valley, Washington
Harris Township, Indiana	Union Township, Indiana
Howard, Wisconsin	Vail, Colorado
LaGrange, Wisconsin	Warran Township, Indiana
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