Fire Apparatus Manufacturer's Association

Fire Apparatus Duty Cycle White Paper

FAMA Technical Committee
Chassis Subcommittee

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Contents

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)

	Custom	Commercial
Pumper	77%	23%
Aerial	93%	7%
Rescue	46%	53%

Life Expectancy

Years Expected in Active Service (Average)

Newest Pumper	17
Newest Aerial	19
Newest Rescue	15

Years Expected in Reserve Service (Average)

Newest Pumper	12
Newest Aerial	10
Newest Rescue	9

Annual Apparatus Usage

Total Miles Driven In Last 12 Months

Newest Pumper	4,501
Newest Aerial	3,663
Newest Rescue	4,898

Total Engine Hours (Average)

	Last 12 Months	Hours per Week
Newest Pumper	655	12.6
Newest Aerial	413	7.9
Newest Rescue	705	13.5

Runs (Average)	Runs per Week	Runs per Year
Newest Pumper	15	780
Newest Aerial	10	520
Newest Rescue	16	832

Hours at Idle Per Week	
Newest Rescue	10
Newest Pumper	9
Newest Aerial	7

Life Expectancy by Demographics

Years of Apparatus in active service (Average Expected)

	Urban	Suburban	Rural
Newest Pumper	15	16	18
Newest Aerial	18	19	21
Newest Rescue	13	15	16

Years of Apparatus in reserve service on (Average Expected)

	Urban	Suburban	Rural
Newest Pumper	10	11	14
Newest Aerial	9	10	13
Newest Rescue	7	7	11

Years of total service life (active plus reserve)

	Urban	Suburban	Rural
Newest Pumper	25	27	32
Newest Aerial	27	29	34
Newest Rescue	20	22	27

Apparatus Use by Demographics

Miles driven (last 12 months)

	Urban	Suburban	Rural
Newest Pumper	7,629	4,992	3,034
Newest Aerial	5,083	3,492	2,155
Newest Rescue	7,534	6,087	3,946

Engine hours (last 12 months)

	Urban	Suburban	Rural
Newest Pumper	873	572	496
Newest Aerial	540	403	279
Newest Rescue	714	648	745

Runs per Week

	Urban	Suburban	Rural
Newest Pumper	29	16	8
Newest Aerial	13	11	5
Newest Rescue	31	16	11

Idle Time (hours per week)

	Urban	Suburban	Rural
Newest Pumper	11	10	6
Newest Aerial	8	7	5
Newest Rescue	13	9	8

Run Length (Round-Trip)	Miles
Urban	4.9
Suburban	5.4
Rural	7.6

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
Grand Total	76	26

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
Rural Total		**2,347**
Suburban	Pumper	6,068
	Aerial	3,479
	Rescue	4,992
Suburban Total		**5,403**
Urban	Pumper	6,126
	Aerial	6,514
	Rescue	9,222
Urban Total		**6,478**
Grand Total		**5,222**

Average Engine Hours Per Year By Demographic

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

Average Pump Hours Per Year By Demographic

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

Average Aerial Hours Per Year By Demographic

Demographic	Apparatus Type	Average of Aerial Hours Per Year
Rural	Aerial	63
Rural Total		**63**
Suburban	Aerial	64
Suburban Total		**64**
Urban	Aerial	72
Urban Total		**72**
Grand Total		**69**

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%
Pumper Total		**66%**	**27%**	**7%**
Aerial	Rural	73%	19%	9%
	Suburban	68%	27%	5%
	Urban	73%	22%	5%
Aerial Total		**71%**	**23%**	**5%**
Rescue	Rural	51%	42%	7%
	Suburban	77%	17%	7%
	Urban	57%	32%	11%
Rescue Total		**61%**	**30%**	**9%**
Grand Total		**67%**	**26%**	**7%**

Time Spent at Engine Load by Demographic

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

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 and average power load for the entire sample population.

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

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

Acknowledgements

I wish to thank all the fire service personnel who assisted in this project. Hundreds of Chiefs responded to our survey, or gave permission to inspect their apparatus. The gathering of this data involved many visits to fire stations where I was allowed to take their apparatus out of service while the data was collected. I have never visited a fire station where I was not welcomed and treated with curtsey. Perhaps a friendly attitude is a natural characteristic of those who put their life on the line to protect others. Whatever the reason, I find it a pleasure playing a small part in a profession filled with such kind people.

– Roger Lackore, Pierce Manufacturing

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East Troy, Wisconsin
Fivepointville, Pennsyvania
Freedom, Wisconsin
Ft Atkinson, Wisconsin
Glenwood Springs, Colorado
Greenville, Wisconsin
Hand In Hand, Pennsyvania
Harris Township, Indiana
Howard, Wisconsin
LaGrange, Wisconsin
Lakeville, Indiana
Liberty, Pennsylvania
Lincoln, Pennsylvania
Lincolnshire, Illinois
Los Angeles, California
Madison, Wisconsin
Marshall, Wisconsin
Mesa, Arizona
Milwaukee, Wisconsin
Mishawaka, Indiana
Monona, Wisconsin
Mount Pleasant, Wisconsin
Mukwonago, Wisconsin
North Shore, Wisconsin
Plymouth, Indiana
Portage Township, Indiana
Racine, Wisconsin
Riverside County, California
Seymour, Wisconsin
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