International Journal of Automotive Technology, Vol. 6, No. 4, pp. 333−340 (2005)

MEASUREMENT OF OPERATIONAL ACTIVITY FOR NONROAD DIESEL CONSTRUCTION EQUIPMENT

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(Received 17 May 2004; Revised 17 March 2005)

ABSTRACT−In order to better quantify the contribution from nonroad sources to emission inventories, it is important to understand not only the emissions rates of these engines but also activity patterns that can be used to accurately portray their in-use operation. To date, however, very little information is available on the actual activity patterns of nonroad equipment. In this study, a total of 18 pieces of nonroad equipment were instrumented with collected data including intake manifold air pressure (MAP), exhaust temperature and, on a subset of vehicles, engine rpm and throttle position. The equipment included backhoes, compactors, dozers, motor graders, loaders and scrappers used in applications such as landfilling, street maintenance and general roadwork. The activity patterns varied considerably depending on the type of equipment and the application. Daily equipment operating time ranged from less than 30 minutes to more than 8 hours, with landfill equipment having the highest daily use. The number of engine starts per day ranged from 3−11 over the fleet with an average of 5 starts per day. The average percent idle time for the fleet was approximately 25% with a range from 11 to 65% for individual pieces of equipment. Duty cycles based on exhaust temperature/throttle position profiles were also developed for two graders and one dozer.

KEY WORDS : Nonroad, Off-road, Diesel, Emission, Inventory, Vehicle activity, Construction equipment

1. INTRODUCTION

For decades, emissions from on-road emissions sources have been the dominant factor in mobile source emissions inventories. Over time, however, the on-road contribution has been substantially reduced, primarily due to the success of improved emissions control technology in meeting regulations. As the on-road emissions have continued to decline, it has become more important to better understand and quantify the contribution of nonroad vehicles to the emissions inventory. United States Environmental Protection Agency (EPA) estimates indicate that nonroad diesel engines currently contribute 20% of the nitrogen oxide (NO_x) emissions and 36% of the particulate matter (PM) emissions from mobile sources in the United States [US] (EPA, 2000a, b). It is anticipated that the relative contribution of these sources will continue to increase as on-road emissions continue to be reduced.

In order to better understand the emissions contribution from nonroad sources, it is important to not only have the emission rates of these engines, but also activity patterns that can be used to accurately portray their in-use operation. In the early 1990s, EPA published a comprehensive study of the factors contributing to emissions from nonroad sources, including population, activity, and emission factors (EPA, 1991). The emissions inventories developed in this study were primarily based on steady state engine tests combined with some Federal Test Procedure engine data and adjustment factors for activity and deterioration. These emission factor estimates were updated in 1998 for the development of EPA's nonroad emission inventory model (EPA, 1998).

·A number of studies over the past several years have evaluated the activity and operation patterns of nonroad equipment and how this information is integrated into emission factors and emission inventory estimates. The US EPA in conjunction with the Engine Manufacturers Association (EMA) conducted a joint study to develop typical operation cycles for an agricultural tractor, a crawler dozer, and a backhoe loader (Jackson and Helmer, 2001). The test cycles developed from instru-

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**Corresponding author.* e-mail: durbin@cert.ucr.edu menting these pieces of equipment were then used in engine dynamometer tests to develop factors to adjust the steady state emission factors to in-use conditions (Fritz, 1998). Researchers at the Northeast States for Coordinated Air Use Management (NESCAUM) and Environment Canada developed in-use test cycles at the Big Dig construction project in Boston, MA by gathering exhaust temperature measurements and video taping equipment during operation (Alnslie *et al.*, 1999). These cycles were subsequently used for in-use emission measurements on a backhoe, two front end loaders, a bulldozer, and a dumptruck. Gautam *et al.* (2002) made measurements of engine speed and raw exhaust emissions on a street sweeper, a rubber-tire loader, an excavator, and a track-type tractor. These researchers than pulled the engines from these pieces of equipment and used engine dynamometer testing and carbon dioxide (CO_2) measurements to infer in-field engine power. Pollack *et al.* (1999) also developed activity estimates from surveys and used this information in combination with project valuation/tonnage activity to provide activity estimates for the Houston area. These estimates were developed for a number of types of construction jobs including residential, commercial, public works, roadway, landfill, mining, and port activity.

While there has been some progress in better understanding emissions from nonroad vehicles, the data available is still very limited in terms of activity patterns and frequency of use. The focus of the present study is to evaluate the operational patterns and activity of nonroad equipment during typical operation. For this study, activity data were obtained for a subset of vehicles from five different fleets within the Southern California area. Vehicles were instrumented with a data logger to obtain intake manifold air pressure (MAP), exhaust temperature and, on a subset of vehicles, engine revolutions per minute (rpm) and throttle position. Using this information, statistics were developed for the daily operational time, the number of starts per day, and the percentage of time at idle. For a subset of equipment, duty cycles in terms of throttle position and exhaust temperature were also developed. The results of this study are summarized in this paper.

2. EXPERIMENTAL PROCEDURES

2.1. Description of Vehicle Fleet

For this program, activity measurements were made on construction equipment from five different fleets in the Southern California Area. These fleets included the City of Riverside, CA fleet, the County of San Bernardino, CA fleet, the County of Riverside, CA fleet and the fleets at the Colton, CA Landfill and the Badlands landfill in Moreno Valley, CA. The range of fleets studied provided a broad survey of different applications of these equipment. The fleets and test equipment selected for this

Table 1. Descriptions of test vehicles.

Vehicle model	Description	Engine year	Engine model	Size (L)	Engine hours	Location
CAT 140-G	Grader	1989	3306	10.5	11,137	BL
CAT D9-L	Dozer	1987	3412	27	24,945	BL
John Deere 670B	Grader	1993	6068T	6.8	3,891	RCo
CAT 936	Loader	1985	3126	7.0	3,201	RC
CAT 926	Loader	1987	3204	5.2	9,969	RC
John Deere 510C	Backhoe	1989	4045T	4.5	5,289	RC
John Deere 410D	Backhoe	1992	4045	4.5	3,792	RC
John Deere 710D #1	Backhoe	1995	6059T	5.7	4,223	RC
John Deere 710D #2	Backhoe	2000	6059T	6.8	1,175	RC
John Deere 710D #3	Backhoe	2000	6059T	6.8	1,181	RC
John Deere 410G	Backhoe	2001	4045T	4.5	263	RC
CAT 163H	Grader	1997	3306	10	6,667	SBC
CAT IT38G	Loader	2001	3126DITA	7.2	1385	SBC
CAT D8RWHA	Dozer	1997	3406	14.6	9,696	CL
CAT D8L	Dozer	1983	3408T	16	8,524	CL
CAT 836S	Compactor	1995	3408E	18	18,529	CL
CAT 140G	Grader	1984	3306	10.5	2,107	CL
CAT 623E	Scrapper	1986	3406	14.6	1,340	CL

BL: Badlands landfill; RCo: Riverside County; RC: Riverside City; SBC: San. Bern. County; CL: Colton landfill.

program were ones that were readily available, could be instrumented at times convenient to the operators, and were anticipated to be operating during the period of instrumentation. The City of Riverside fleet was primarily composed of backhoes used for trenching and other street maintenance operations. The Colton and Badlands landfill sites incorporated typical equipment found at a landfill including dozers, compactors, motor graders, and scrapers. The County of San Bernardino had pieces of equipment such as a motor grader and a front loader used in the maintenance of flood control areas and associated roads. A motor grader was also tested for the County of Riverside. A listing of the equipment instrumented is provided in Table 1, along with information such as engine type and size and engine hours.

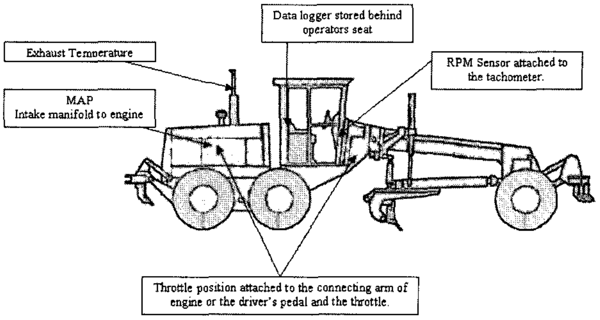

Figure 1. Schematic diagram of the logging system for a John Deere 670B Grader.

2.2. Description of Test Instruments

The main focus of this program was to obtain information of the usage activity of the different nonroad equipment. Broadly, this included daily operational time, the number of starts per day, and average idle time. This information was obtained based on a range of different activity parameters that were measured. For a majority of this equipment, this included exhaust temperature and intake MAP. For some vehicles, additional data on engine rpm and throttle position were also obtained. Videotaping was also done on some of the days of operation for the equipment located at the Badlands landfill.

Over the course of the program, two different data loggers were employed, a Campbell CR 10-X data logger and a Hyperlogger data logger from Logic Beach (San Diego, CA). Both data loggers had multiple inputs that could be used for tracking a range of operating parameters, although the subset of parameters collected differed between the two data loggers and the different sampling periods. The Campbell CR 10-X data logger was used primarily to collect exhaust temperature and throttle position data. The HyperLogger data logger system was used on a different subset of equipment, and was primarily used to collect exhaust temperature, MAP, engine rpm, intake air temperature, ambient air temperature, and ambient air pressure. Both systems had sufficient memory size for collection of multiple days of data, although the Hyperlogger was limited by battery capacity.

A schematic diagram of the data logger and input sensors set-up is provided in Figure 1. The exhaust temperature measurements were made using a K-type thermocouple for all runs for both the Campbell and HyperLogger data loggers. MAP measurements were obtained by measuring the pressure at the intake service test port, which is typically located between the turbocharger and the engine intake manifold. Engine speed was determined by measuring the signal from by the tachometer output for a subset of equipment monitored using the Hyperlogger data logger. Measurements of throttle position were made using a 0 to 5 V potentiometer attached to the connecting rod from the accelerator to the engine. The potentiometer's signal had a linear relationship to the throttle position.

3. RESULTS

3.1. Frequency of Use Results

The activity patterns developed for each piece of equipment varied considerably based on the type of equipment and application. A summary of the activity results is provided in Table 2. Since the Campbell system did not provide sufficient information to characterize these activity details, Table 2 includes only the equipment instrumented with the HyperLogger system. More detailed results of the activity for each test day are provided in Attachment A.

The actual determination of the vehicle activity was made using both engine rpm and MAP. The periods of time spent in the fully operating, idling, and engine-off modes could be easily determined for equipment where rpm data were available. The MAP was used to determine the three phases of equipment operating, idling, and engine-off when rpm was not available. The three modes of operation resulted in three distinct traces of the MAP curve. The MAP sensor read a constant value corresponding to one atmosphere when the engine was fully turned off. The MAP sensor also read a value close to one atmosphere when the engine was idling, but showed some small fluctuations as opposed to a constant value. It should be noted that only instances where the equipment was found to be idling for a period of more than one minute are included in the percent idle time calculation. In contrast, during the periods of regular operation, the MAP reading was highly transient. An illustration of the differences in the MAP signal is provided in Figures 2(a) and 2(b), respectively, for a compactor at the Colton landfill and a City of Riverside backhoe.

Table 2. Summary of daily activity by vehicle.

Vehicle model	Description	# Days	Total operating time	# Starts per day	% Time at idle
CAT 936	Loader	1	1:06:18	6	30
CAT 926	Loader	2	1:51:35	4.5	11
John Deere 510C	Backhoe	2	0:23:00	5	15
John Deere 410D	Backhoe	1	0:42:34	3	65
John Deere 710D #1	Backhoe	1	0:31:52	3	13
John Deere 710D #2	Backhoe	5	1:25:35	11	31
John Deere 710D #3	Backhoe	2	1:15:09	6.5	44
John Deere 410G	Backhoe	1	2:09:23	6	27
CAT 163H	Grader	3	5:10:35	4.3	16
CAT IT38G	Loader	3	2:13:14	4	24
CAT D8RWHA	Dozer	5	7:08:15	3.6	14
CAT D8L	Dozer	5	5:45:29	2.4	28
CAT 836S	Compactor	4	8:12:32	4.75	12
CAT 140G	Grader	4	2:13:19	5.75	19
CAT 623E	Scrapper	6	2:59:35	3	34

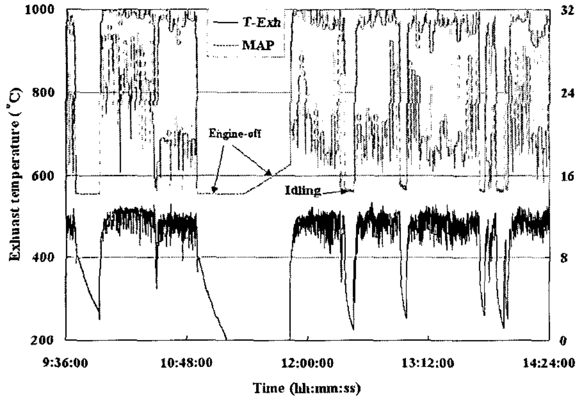

Figure 2(a). MAP and exhaust temperature profile, Compactor at Colton landfill.

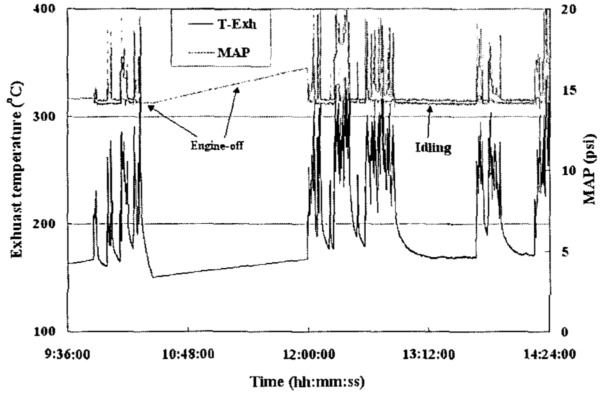

Figure 2(b). MAP and exhaust temperature profile, Backhoe at Riverside city.

The equipment at the landfill sites tended to be the most extensively used. The dozers and compactors, in particular, are operated extensively throughout the day from start-up to shut down arranging and compacting the waste for burial and arranging the night-time cover for the landfill. The average operational time for the dozers and compactors ranged between nearly 6 to just over 8 hours per day. The scrapper at the landfill is used as needed to transport soil between different locations. The average operational time for the scraper was approximately 3 hours. Of the equipment at the landfill, the motor grader was the least extensively used with an average daily use of about 2 hours. The motor grader is essentially used to ensure the paths at the landfill are maintained in conditions that can be traveled by the traffic.

The equipment for the Riverside City municipal operations did not operate as extensively as the landfill equipment on a per day basis. This equipment was stationed at a central location and transported to different job sites each day. The backhoes instrumented were primarily ones associated with the water department and were used mostly in street maintenance operations. During a particular day's operation, the backhoes were essentially used as needed in performing a particular assigned task. As such, their daily time of operation was typically less than that observed for the landfill vehicles, with daily operation times ranging from 20 minutes to 2 hours. Two loaders used by the City of Riverside were also instrumented. Their operational times were between 1–2 hours per day.

The two pieces of equipment for the San Bernardino

County fleet were mainly used in the maintenance of flood control infrastructure. For the three days of field-testing, the motor grader was used quite extensively with an average daily operational time of just over 5 hours. The use pattern for the loader, on the other hand, varied more extensively depending on the test day, with limited use on some of the test days and an average daily operation time of just over 2 hours.

The number of starts per day and the percentage of time spent at idle also varied between different pieces of equipment and for different applications. The number of engine starts per day ranged from 3–11 over the fleet with an average of 5 starts per day. The number of starts per day was not found to be directly related to the operation time of the vehicle. In fact, the more extensively used equipment at the landfill actually had a similar number of starts on average compared to the equipment for the City of Riverside. This is probably due to the more continuous operation of the landfill vehicles. The idle time also varied significantly between the different test equipment. Over the fleet, the percent of idle time varied from 11% to 65%. The average percent idle time for the three different fleets was between 20-30%, with the total fleet average being approximately 25% idle time.

3.2. Duty Cycles and Activity Patterns

Additional analysis was conducted to develop duty cycles representative of the in-use activity data collected for the equipment where throttle position was measured with the Campbell data logger. This included one motor grader from the county of Riverside and a motor grader and a dozer from the Badlands landfill. These data sets were initially analyzed by developing a matrix of the number of event occurrences and the percent of time spent at different throttle position/exhaust temperature combinations. A profile for the grader used by the County of Riverside is given in Figure 3. This piece of equipment is used for grading dirt shoulders on the roads. The profiles in Figure 3 show that this equipment spends a majority of its operation in one of two regimes, idle or full throttle. The abundance of data in the idle range is due to the operator waiting for traffic to slow down for a safe path to do his work. A preliminary visual analysis and verbal consultation with operators yielded that this pattern is characteristic of many of the county's roadwork vehicles. The full throttle operating regime is due to the nature of the equipment which is typically used at full throttle.

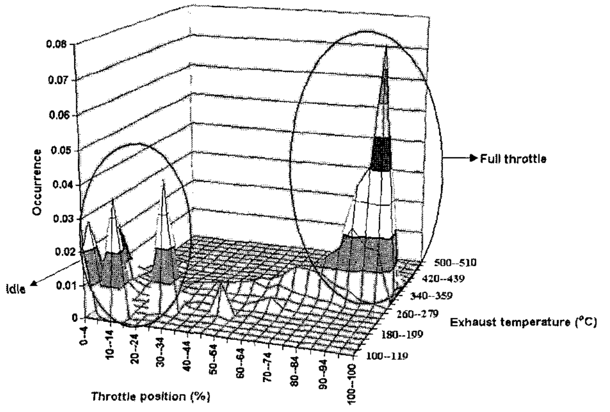

Figure 3. Occurrence of various combinations of throttle position and exhaust temperature for a John Deere 670B Grader.

After developing the throttle position/exhaust temperature profiles, the data were divided into identifiable microtrips. Microtrips were identified using the time stamp of the video tape and data logger. Each microtrip was defined as a stop followed by a forward, a reverse, and then another stop. This definition was used to ensure the cycle would be "drivable" with equal number of forwards and reverses. Each microtrip was anywhere from 15 seconds to 6 minutes in duration. It should be noted that since the microtrips contain no periods of idle, subsequent comparisons were also made with the in-field data with the idle period removed. Randomly selected microtrips were than appended together to yield a test cycle with a duration of 20 ± 0.5 minutes. The randomly generated cycles were then compared to the data collected over the entire work week. Comparisons were made using the percent occurrence matrices for both data sets. The two matrices were compared using the sum of the squares of the difference of the value of each bin. An Microsoft Excel™ macro was generated to run through a series of cycles until a threshold value for the sum of squares was obtained. For each vehicle, close to 2,000 random cycles were evaluated. The ten cycles with the lowest sum of squares values were kept for further comparisons.

Although this gave a relative comparison of the cycles, the sum of squares value did not provide any "real measure" of the deviation of the cycle from the overall data. In order to address this issue, the Kolmogorov-Smirnov Two-Tailed Test (K-S) was used (Siegel, 1956). This test is commonly used to determine if two samples have been drawn from the same population. The K-S is sensitive to any differences in the distributions such as dispersion, skewness, and central tendency. Any such difference is reflected in the results of the test. The test is applied by comparing the cumulative distributions between the duty-cycle being evaluated and the actual in-field data. In this case, the K-S test was applied to the cumulative distributions of throttle position/exhaust temperature. An example of the comparison of cumulative distributions for throttle position/exhaust temper-

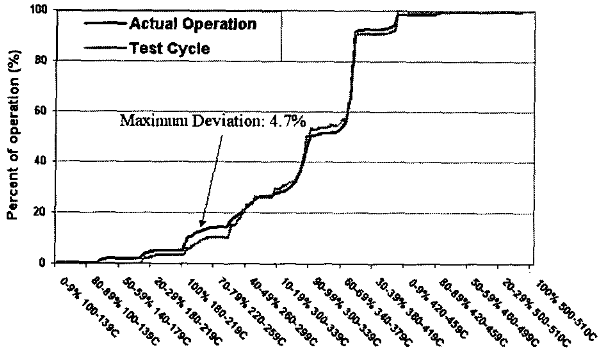

Figure 4. Cumulative distribution of temperature/throttle matrices for the grader and test cycle.

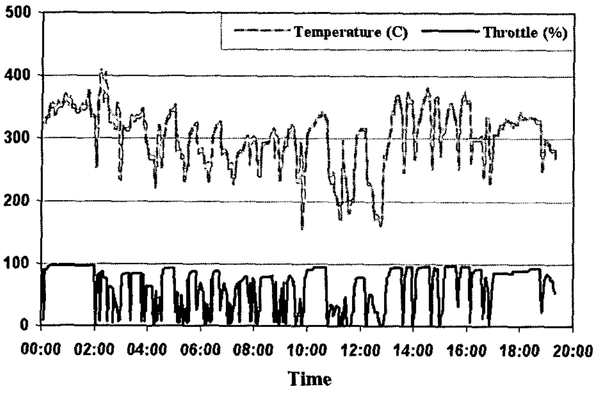

Figure 5. Grader test cycle.

ature is provided in Figure 4 for the grader test cycle. Here, the throttle position/exhaust temperature distributions are separated into bins, resulting in the step function nature of the curve. This graph shows the maximum deviation in the cumulative distribution for the grader cycle is 4.7% in the low throttle position, mid-temperature range.

The generated test cycle for the grader shown in Figure 3 is presented in Figure 5. The amount of data collected from the grader at the County of Riverside Pedley yard was insufficient to produce a representative test cycle. As a result, the data was combined with the data from the grader at the Badlands landfill and a composite test cycle was made for a grader.

The throttle position/exhaust temperature matrix for the in-field data for the grader and the generated test cycle data for the grader are provided in Figures 6(a) and 6(b), respectively, for comparison. As seen, the peak at the high temperature, high throttle region for the test cycle is comparable to that in the in-field data. In the 260 to 290°C high throttle region, the peak is slightly higher but not as wide, leading to some small deviations that are statistically insignificant. The maximum deviation of 4.7% can be seen in the 200 to 260°C mid-throttle region. Overall, these cycles are a relatively good representation of the overall data.

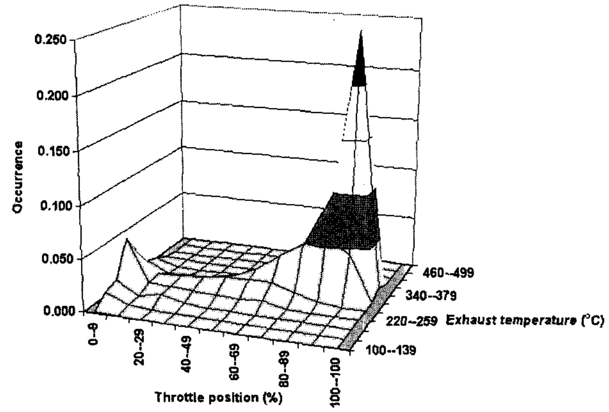

Figure 6(a). In-field vs. test cycle grader throttle/temperature matrix: In-field.

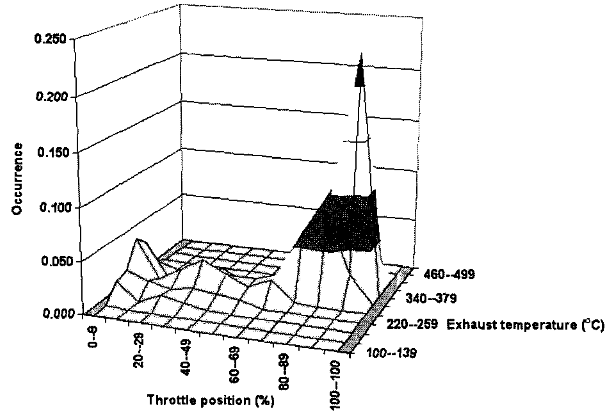

Figure 6(b). In-field vs. test cycle grader throttle/temperature matrix: Test cycle.

While these cycles provide important information on nonroad equipment activity patterns and a framework for developing future cycles based on in-use activity, they could also potentially be used to help collect more realistic emissions data from nonroad equipment. Ainslie *et al.* (1999) have previously used exhaust temperature profiles in combination with video tape of operation to develop repeatable cycles for evaluating emissions from nonroad vehicles in the Boston, MA Big Dig study. The video tape segments were used to develop test tracks or repeatable patterns that could be used to represent normal operating activity. Exhaust temperatures made during emissions tests were then compared with those made during actual operation to evaluate the success of the test patterns in simulating actual operation. Similar test tracks could be developed for the following cycles by examining the video tape sections related to each of the microtrips included in the cycle and using these trips as different portions of a test track. More comprehensive cycles could also be developed using the same statistical techniques combined with measurements of rpm and engine load or measurements of CO_2 that can subsequently be extrapolated on an engine dynamometer test stand to determine load (Gautam *et al.*, 2002). Although throttle position is closely related to engine load, it is suggested that a more direct measurement of engine load may be needed to development more detailed information for engine cycles. While the measurement of exhaust emissions and direct engine load are beyond the scope of the current study, additional work in this area will continue expand the knowledge base of nonroad equipment emissions. The statistical methods used in the development of the current exhaust temperature vs. throttle position cycles could be utilized in conjunction with more detailed load measurements in the further development of nonroad test cycles.

4. SUMMARY AND CONCLUSIONS

The objective of this study was to evaluate the activity levels of diesel equipment to better understand the in-use activity of these vehicles. A total of 18 pieces of nonroad equipment were instrumented for periods of between one day and one week. A variety of different equipment was instrumented including dozers, backhoes, compactors, loaders, graders and scrappers. The equipment also represented different types of operation including landfilling, street maintenance work, and work on roadways and flood control infrastructure. The data collected throughout the program included intake manifold air pressure (MAP), exhaust temperature and, on a subset of vehicles, engine rpm and throttle position. Some of the major results of this study are as follows:

(1) The activity patterns of nonroad equipment vary considerably depending on the type of equipment and the application. The daily equipment engine operating time ranged from less than 30 minutes to more than 8 hours. The equipment used at the landfill had the highest typical daily operating time while the equipment used by the city for street maintenance had the lowest typical daily operating time.

(2) The number of engine starts per day ranged from 3–11 over the fleet with an average of 5 starts per day. Interestingly, the equipment with the longest daily operation time actually had similar number of starts to the less extensively used equipment. This can probably be attributed to the more continuous use of this equipment throughout the day.

(3) The average percent idle time for the fleet was approximately 25% with a range between 20–30% for the different fleets. For individual equipment, the percent of idle time varied from 11% to 65%.

(4) Duty cycles based on exhaust temperature/throttle position were developed based on statistical comparison using a sum of squares of differences and a Kolmogorov-Smirnov Two-Tailed Test (K-S). Overall, the developed cycles showed good correlation with the actual in-field data collected. Specifically, the cumulative throttle position/exhaust temperature distributions showed deviations of no more than 4-7% at the maximum.

ACKNOWLEDGEMENT–The authors acknowledge Mac MacClanahan who developed and made in-field measurements with the HyperLogger system and Ross Rettig who assisted with the in-field measurements. The authors acknowledge the contribution and support of the staff at the City of Riverside municipal fleet, the staff of Burrtec who operate the Colton landfill site, the staff at the Riverside County Waste Management Department who operate the Badlands landfill, and the staff at the San Bernardino and Riverside County fleets. We acknowledge the United States Environmental Protection Agency for providing funding for this program under Cooperative Agreement No. R-82954601-0.

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Attachment A. Daily activity by vehicle for each test day.

Model	Description	Test Date	Total Operating Time	# of Starts per Day	% Time at Idle	Ave. Operating Time per Start	Ave. non-idle RPM	Ave. idle RPM	Start Time	End Time	Location
CAT D8RWHA	Dozer	05/30/03	7:8:52	1	14.6%	30136			10:51:19	19:17:11	CL
CAT D8RWHA	Dozer	06/02/03	5:9:14	4	10.0%	5154			7:27:29	17:45:03	CL
CAT D8RWHA	Dozer	06/03/03	8:28:9	6	11.1%	5715			6:58:14	17:29:07	CL
CAT D8RWHA	Dozer	06/04/03	6:45:55	3	16.4%	9709			9:23:40	17:56:39	CL
CAT D8RWHA	Dozer	06/05/03	8:9:7	4	17.3%	8877			6:44:31	17:37:42	CL
CAT D8L	Dozer	06/10/03	6:1:40	1	28.9%	30537			9:28:34	17:57:30	CL
CAT D8L	Dozer	06/11/03	8:18:5	2	15.5%	17686			7:42:51	17:58:07	CL
CAT D8L	Dozer	06/12/03	4:55:52	3	20.7%	7463			7:12:51	17:45:55	CL
CAT D8L	Dozer	06/13/03	4:20:36	3	33.6%	7853			9:40:34	17:33:31	CL
CAT D8L	Dozer	06/16/03	5:11:13	3	40.9%	10523			7:18:43	18:01:53	CL
CAT 836S	compactor	06/17/03	7:50:55	6	13.7%	5456			7:04:54	16:50:14	CL
CAT 836S	compactor	06/18/03	8:16:15	4	17.2%	8989			7:14:33	18:30:06	CL
CAT 836S	compactor	06/20/03	7:42:17	4	10.5%	7744			7:19:35	16:59:10	CL
CAT 836S	compactor	06/23/03	9:0:39	5	6.9%	6968			7:08:10	16:59:06	CL
CAT 140G	Grader	06/24/03	2:46:37	8	12.5%	1429			7:24:59	17:50:03	CL
CAT 140G	Grader	06/26/03	3:11:7	4	14.3%	3345			11:00:22	18:22:48	CL
CAT 140G	Grader	06/27/03	1:5:0	6	34.2%	988			9:06:48	17:32:44	CL
CAT 140G	Grader	06/30/03	1:50:30	5	16.7%	1593			11:06:59	16:55:36	CL
CAT 623E	Scraper	07/02/03	1:52:40	3	31.1%	3271			15:03:13	18:03:23	CL
CAT 623E	Scraper	07/03/03	0:40:32	1	22.5%	3138			6:18:17	7:10:35	CL
CAT 623E	Scraper	07/07/03	5:3:58	4	31.6%	6671			8:47:37	18:27:52	CL
CAT 623E	Scraper	07/08/03	1:55:29	3	48.9%	4517			10:36:21	17:58:13	CL
CAT 623E	Scraper	07/09/03	2:42:14	4	46.4%	4540			7:56:09	17:55:35	CL
CAT 623E	Scraper	07/10/03	5:42:37	3	23.6%	8975			9:10:38	17:43:22	CL
CAT 163H	Grader	12/03/02	3:52:51	4	9.2%	3848	608	313	7:33:38	12:48:42	SBC
CAT 163H	Grader	04/02/03	5:50:34	4	20.9%	6650	631	282	8:17:42	16:15:14	SBC
CAT 163H	Grader	04/03/03	5:48:20	5	19.3%	5179	601	282	8:13:58	16:07:53	SBC
CAT IT38G	Loader	08/06/03	0:58:37	2	24.5%	2331			7:21:43	8:44:07	SBC
CAT IT38G	Loader	08/08/03	3:5:6	5	11.2%	2501			8:07:19	17:00:59	SBC
CAT IT38G	Loader	08/13/03	2:35:58	5	35.0%	2882			7:34:12	16:10:16	SBC
John Deere 410D	Backhoe	03/05/03	0:42:34	3	65.2%	2446	563	217	7:53:21	14:31:35	RC
CAT 926	Loader	09/20/02	3:31:53	3	21.0%	5362			6:45:03	11:25:28	RC
CAT 926	Loader	10/01/02	0:11:18	6	0.0%	113			16:54:17	22:23:36	RC
CAT 936	Loader	09/24/02	1:6:18	6	30.4%	953			6:53:08	16:26:32	RC
John Deere 710D	Backhoe	09/13/02	0:31:52	3	13.0%	733			7:05:51	8:22:14	RC
John Deere 410G	Backhoe	09/17/02	2:9:23	6	26.9%	1770			7:19:02	13:56:04	RC
John Deere 710D #3	Backhoe	09/25/02	1:26:6	6	58.8%	2090			6:47:53	16:01:07	RC
John Deere 710D #3	Backhoe	10/10/02	1:4:13	7	28.7%	772	2167	933	8:29:43	16:09:31	RC
John Deere 710D #2	Backhoe	09/26/02	1:24:15	12	10.1%	468			8:17:36	15:45:16	RC
John Deere 710D #2	Backhoe	10/09/02	0:29:31	11	58.1%	384	1800	888	8:19:04	17:10:21	RC
John Deere 710D #2	Backhoe	04/15/03	1:21:32	9	35.4%	841	505	237	7:09:17	13:53:33	RC
John Deere 710D #2	Backhoe	04/16/03	1:44:13	14	16.9%	537	476	241	7:13:15	13:33:15	RC
John Deere 710D #2	Backhoe	04/17/03	2:8:23	9	35.3%	1323			7:18:50	13:40:47	RC
John Deere 510C	Backhoe	05/08/03	0:26:19	5	5.7%	335	348	197	8:13:04	10:07:41	RC
John Deere 510C	Backhoe	05/09/03	0:19:42	5	24.8%	314	445	196	10:59:39	13:18:32	RC

CL: Colton landfill; SBC: San. Bern. County; RC: Riverside City