DEVELOPMENT OF ORGANIC GAS SPECIATION PROFILES AND EMISSION FACTORS FOR NONROAD SPARK IGNITION AND COMPRESSION IGNITION ENGINES AND EQUIPMENT

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INTRODUCTION

The composition of exhaust emissions from nonroad engines and equipment varies based on a number of parameters, including engine/equipment type, emission control technology, fuel composition, and operating conditions. Speciated emissions data which characterize the magnitude and chemical composition of these emissions are needed to develop chemical speciation profiles which are used for air quality modeling and development of air toxics inventories. Improvements in the quality of these data will result in more accurate emissions and air quality modeling.

The best available speciated total organic gas data sets for engines with different levels of emission controls on representative fuels were used to create exhaust speciation profiles and emission factors for a variety of nonroad spark ignition (SI) engines (Carroll, 2010) and compression ignition (CI) engines (Starr, 2004a and 2004b). We discuss differences found in SI engine chemical composition between 2-stroke and 4-stroke engines, and E0 and E10 fuel blends, and differences between CI engine profiles with regards to engine control tiers, horsepower, and engine test cycles.

TEST ENGINES

Table 1. Off-Road Spark-Ignition Test Equipment and Engines

Type	Year	Stroke	Engine Make/Model	Equipment Make/Model
22" Mower	2006	4	Briggs & Stratton 10T5..	MTD 11A-084F229
Mower	2007	4	Honda GXV160	Honda HRC 2163HXA
Riding Mower	2007	4	Techumseh OV 358 EA	MTD 638RL Yard Machine
Riding Mower	2007	4	Kawasaki FH641V-ES25-R	Snapper S150X
Generator	2004	4	Briggs & Stratton 1015499427	Briggs & Stratton Elite Series 6200 30386
Generator	2006	4	Honda GX620KI	Honda EB11000
Blower	2007	4	Makita EHO25	Makita BHX2500
NRMC	2007	2	Honda CR125	
NRMC	2002	2	Kawasaki KX250	
ATV	2006	2	Yamaha Blaster	
ATV	2002	2	Polaris Trailblazer	

Table 2. Compression-Ignition Test Engines

Intended Application	Manufacturer	Year/Model	Tier	hp
forklift truck	Kubota	1999 V2203E	1	50
construction equipment	Cummins	1999 QSL9	1	330
rubber-tired loader	Caterpillar	1999 3408	1	480
motor grader	Deere	1996 6068T	0	160
excavator	Cummins	1997 M11C	1	270
agricultural tractor	Caterpillar	2001 3196	2	420
telescoping boom excavator	Cummins	2001 ISB190	1	194

Profiles developed from the SI engine test program:

- 4-stroke uncatalyzed engines running on E0
- 4-stroke uncatalyzed engines running on E10
- 2-stroke uncatalyzed engines running on E0
- 2-stroke uncatalyzed engines running on E10

Profiles developed from the CI engine test programs (steady-state & transient operations):

- Pre-Tier 1 engines
- Tier 1 engines with less than 50 horsepower (hp)
- Tier 1 engines with greater than 50 hp
- Tier 2 engines with greater than 50 hp

RESULTS

Speciation of SI engines was compared across engines and fuels by compound class and by compounds which are large contributors to the profiles (*Figure 1*). Percent composition of compound class was similar between E0 and E10 fuels with the exception of oxygenates (ethanol) whereas chemical composition varied greatly between 2-stroke and 4-stroke engines.

Speciation of diesel engines was compared across CI engine control tier and power rating. Steady-state and transient tests were also compared between CI engine profiles. These comparisons were made by compound class and by chemicals which were emitted in the highest amounts (*Figure 2*).

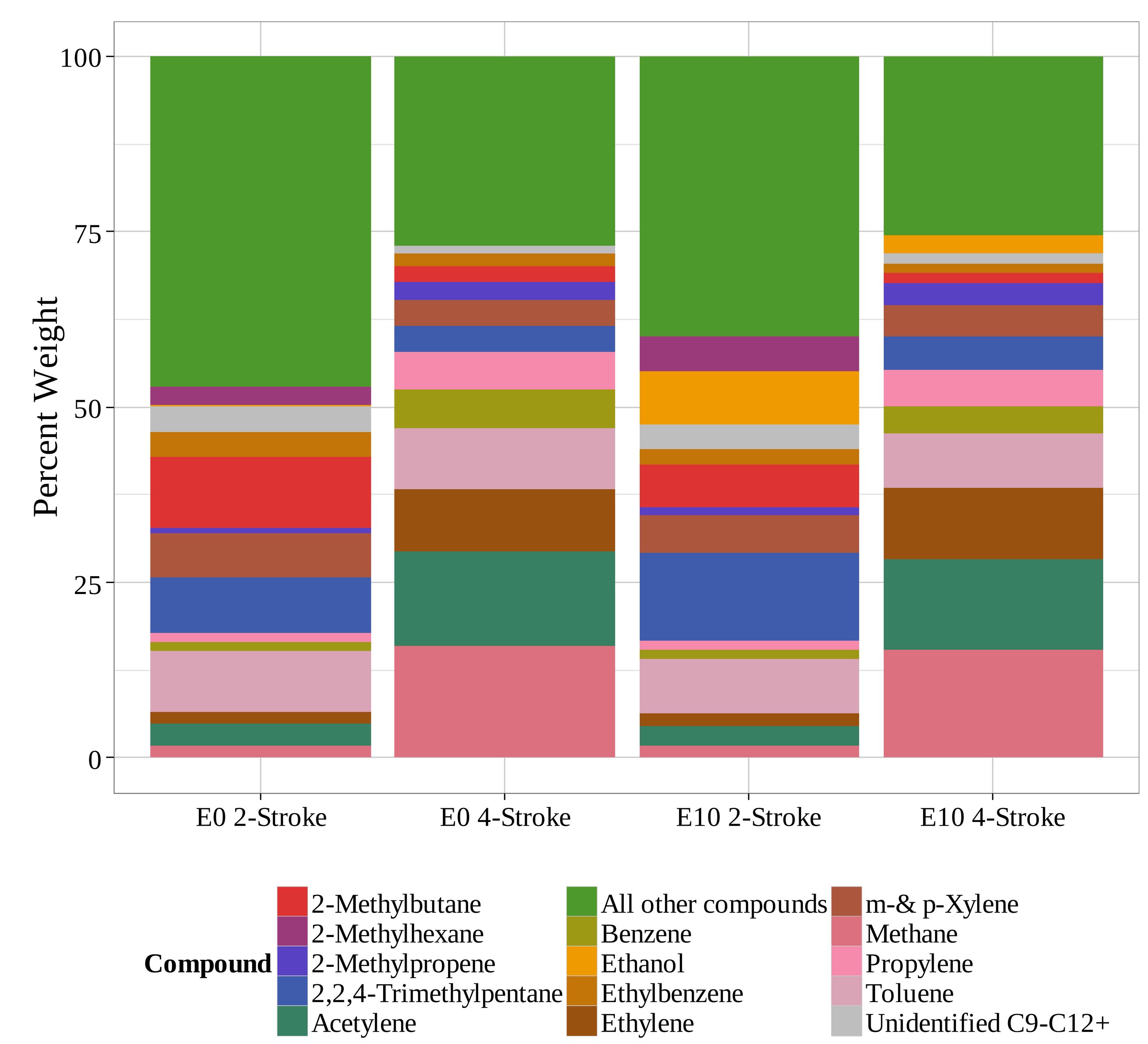

Fig 1. Composite compounds which are the largest contributors to SI profiles.

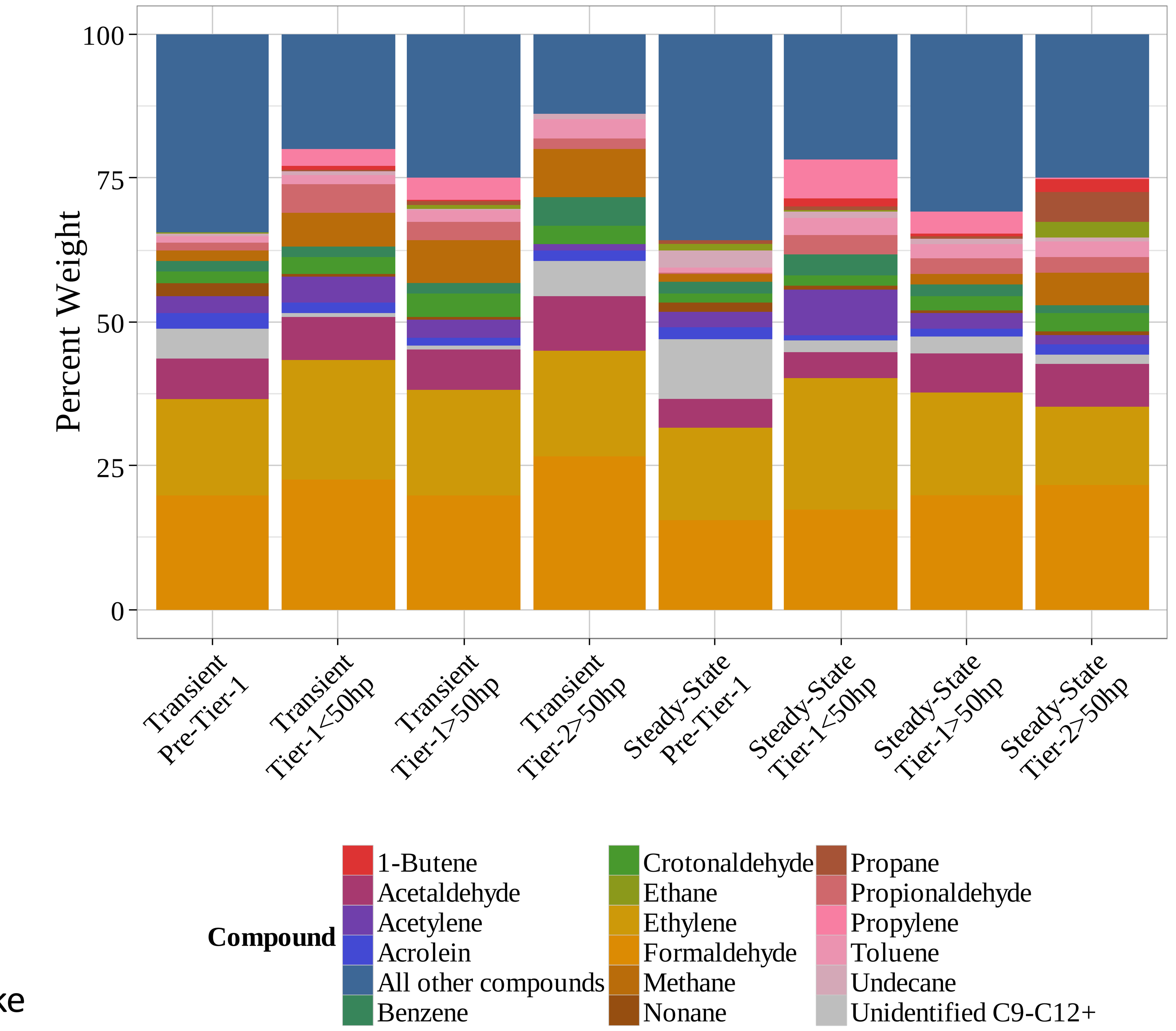

Fig 2. Composite compounds which are the top contributors to CI profiles.

There is more variation between engine control tier and power rating than between steady-state or transient test cycles. However, a few notable differences between test cycles were still present. Tier 1 profiles had differing composition with horsepower across test cycles. These differences are indicated in *Table 3*.

Table 3. Tier 1 CI engine exhaust speciation profile percent differences in mass of emissions between >50hp and <50hp profiles [a]

Compound	% mass difference
Paraffins	42.2, 89.3
Olefins	8.3, 77.1
Aromatics	0.8, 83.9
Crotonaldehyde	35.2, 89.1
Methane	7.7, 100
Propionaldehyde	-48.7, 79.0
Ethylene	12.7, 80.2
Acetylene	-125.3, 41.7
Benzene	8.2, 72.9

[a] Values indicate the percent difference in mass of emissions between Tier 1 >50hp and Tier 1<50hp profiles on transient and steady-state tests, respectively

REFERENCES

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M. Starr (2004b) Nonroad Duty Cycle Testing For Toxic Emissions. US EPA Contract 68-C-98-158, Work Assignment 3-05.