Appendix F

Evaluation of the Use of Alternative Fuels in Cargo Handling Equipment

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Alternative fuels can be used in engines subject to the proposed cargo handling equipment regulation – as long as the engines meet the requirements, which are based on best available control technology (BACT), outlined in the proposed regulation. In-use yard trucks would be required to meet the 2007 or later certified on-road diesel engine standards, the final Tier 4 certified off-road diesel engine standards, or install a verified diesel emission control strategy (VDECS) that will result in the engine meeting equivalent diesel PM and NOx emissions of the final Tier 4 certified off-road diesel engine standards. In-use non-yard truck cargo handling equipment also have several compliance options, which include, but are not limited to, meeting certified on-road or off-road diesel engine standards and/or applying VDECS. A detailed discussion of the requirements is available in Chapter 4 of this Staff Report. These requirements do not specify that diesel fuel be used in cargo handling equipment engines. In fact, they were established for both diesel-fueled diesel engines and diesel engines that use alternative fuels. As such, an engine that meets the requirements of the proposed regulation would be considered BACT if it used diesel or an alternative fuel.

A. Alternative Fuel Types

Liquefied Natural Gas: (LNG) is an odorless, colorless, non-corrosive and non-toxic. When extracted from underground reserves, natural gas is composed of approximately 90 percent methane. During the liquefaction process, oxygen, carbon dioxide, sulfur compounds, and water are removed, purifying the fuel and increasing its methane content to almost 100 percent. As a result, LNG-fueled vehicles can offer significant emissions benefits compared with older diesel-powered vehicles and can significantly reduce carbon monoxide and particulate emissions as well as nitrogen oxide emissions. (EPA, 2002)

Compressed Natural Gas: (CNG) is odorless, colorless, and tasteless. It consists mostly of methane and is drawn from gas wells or in conjunction with crude oil production. CNG vehicles store natural gas in high-pressure fuel cylinders at 3,000 to 3,600 psi. An odorant is normally added to CNG for safety reasons. (EPA, 2002a)

Liquefied Petroleum Gas: (Propane or LPG) is a byproduct of natural gas processing and petroleum refining. In its natural state, propane is a colorless, nontoxic gas -- at least 90 percent propane, 2.5 percent butane and higher hydrocarbons, and the balance ethane and propylene. Under moderate pressure, propane gas turns into a liquid mixture, making it easier to transport and store in vehicle fuel tanks. Compared with gasoline, propane can lower carbon dioxide, carbon monoxide, and other toxic emissions. (EPA, 2002b)

B. Alternative Fuels Specifications (Regulations Concerning Fuel Quality)

The Air Resources Board (ARB) adopted specifications for all alternative motor vehicle fuels can be found in the California Code of Regulations, Title 13, Division 3, Chapter 5, Article 3, Sections 2290-2292.6. When the Board adopted specifications for vehicular alternative fuels[1], it set essentially identical standards for the motor vehicle fuel sold commercially in California and the fuel used for emission standard certification testing of new motor vehicles. The purpose for the commercial fuel specifications is to ensure that motor vehicles certified on alternative fuel will receive in-use fuel having a quality similar to that of a certification fuel, so that vehicles will achieve their emission standards in use.

C. Standards For and Availability of Alternative Fueled Engines

The ARB must certify new motor vehicles and engines for emission compliance before they are legal for sale, use, or registration in California. Certification is granted annually to individual engine families and is good for one model year. Table F-1 lists the on-road heavy-duty engines that are CARB certified using alternative fuels.

Table F-1
2005 CARB Certified Alternative Fueled On-Road Engines

Engine Manufacturer	Fuel Type	Engine Size (L)	Hp	Class	CARB Executive Order #
Cummins	CNG/LNG	5.9	195 - 230	MHDD	A-021-0377
	CNG/LNG	8.3	250 - 280	MHDD	A-021-0381
	CNG/LNG	8.3	250 - 280	UB	A-021-0382
	CNG/LNG	8.9	320	MHDD	A-021-0372
	CNG/LNG	8.9	320	MHDD	A-021-0372-1
	CNG/LNG	8.9	320	UB	A-021-0373
John Deere	CNG	8.1	275 - 280	HHDD	A-108-0035
	CNG	8.1	250	MHDD	A-108-0037
	CNG	8.1	250 - 280	UB	A-108-0036
DDC*	CNG/LNG	8.5	275	UB	A-290-0116
	CNG/LNG	11.9	275	UB	A-290-0117
Mack Truck	CNG/LNG	8.1	325 - 425	HHDD	A-027-0118
Bi-Phase Technology	LPG	8.1	325	HDO	A-360-0003
	LPG	8.1	325	HDO	A-360-0004

MHDD= Medium Heavy Duty Diesel
UB= Urban Bus
HDO= Heavy Duty Off-Road

* DDC no longer offers an alternative fuel engine for sale in California. (ARB 2005d)

[1] Alternative fuels are defined as any fuel which is commonly or commercially known as one of the following: M-100 fuel methanol, M-85 fuel methanol, E-100 fuel ethanol, M-85 fuel ethanol, CNG, LPG, or hydrogen.

The ARB also certifies off-road engines prior to their legal sale, use, or registration in California. Table F-2 lists two certified alternative fueled engines for off-road use in 2005. Both of these engines are also certified for on-road use. The Executive Order (E.O.) # U-R-002-0302 is on-road E.O. # A-021-0377 and E.O.# U-R-002-0303 is on-road E.O. # A-021-0378.

Table F-2
2005 CARB Certified Alternative Fueled Off-Road Engines

Engine Manufacturer	Fuel Type	Engine Size (L)	Hp	Class	CARB Executive Order #
Cummins	CNG/LNG	5.9	195 - 230	MHDD	U-R-002-0302
Cummins	LPG	5.9	185	MHDD	U-R-002-0303

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Table F-3 below lists the on-road emission standards for heavy duty diesel engines along with certification information for an 2005 alternative fueled engine.

Table F-3
Compare 2005 Alternative Fuel Engine Certification and
Heavy-Duty On-Road Engines FTP Transient Test Standard (g/bhp-hr)

Model Year	Fuel	NOx	CO	PM
2005 Certification*	CNG/LNG	1.4 (+HC)	1.0	0.004
Stardard				
1990	Diesel	6.0	15.5	0.6
1991 - 1993	Diesel	5.0	15.5	0.25
1994 - 1998	Diesel	5.0	15.5	0.1
2004	Diesel	2.4 (+nmoc)	15.5	0.1
2007	Diesel	0.2**	15.5	0.01

*Certification for family 5CEXH0359BBG, ARB Executive Order A-021-0377
**phase in schedule, 50% from 2007 to 2009, 100% in 2010. (Diesel, 2002)

Tables F-4 compares two 2005 alternative fuel engine certification levels to the certification standards for off-road engines in the 175 to 300 horsepower range. Diesel emission certification limits are the standard that alternative fuel off-road engines must meet.

Table F-4
Comparison of 2005 Alternative Fuel Engine Certifications and Off-Road Compression Ignition (diesel) Certification Standards (g/bhp-hr)

Year	Type	Horse power	Fuel	NMOC+ NOx	PM	CO
2005	*Off-Road Certification	185	LPG	2.1	0.01	0.8
2005	**Off-Road Certification	195 - 230	CNG/ LNG	1.4	0.004	1.0
1996 Tier 1	Off-Road C.I. Std. (Diesel)	175 to <300	Diesel	7.9	0.4	8.5
2001 Tier 2	Off-Road C.I. Std. (Diesel)	175 to <300	Diesel	4.9	0.15	2.6
2006 Tier 3	Off-Road C.I. Std. (Diesel)	175 to <300	Diesel	2.9	0.15	2.6
2011 Tier 4	Off-Road C.I. Std. (Diesel)	175 to <300	Diesel	1.6	0.01	2.6

*Certification for family 5CEXH0359BBG, ARB Executive Order # A-021-037
** Certification for family 5BPTELPGEFVAP, ARB Executive Order # A-360-004

D. Current Use of Alternative Fuels in Cargo Handling Equipment

Currently, LPG powered forklifts are being used at the Ports of Long Beach and Los Angeles container and dry and break bulk terminals. Container terminals at the POLB had 77 forklifts, 31 (43%) of the forklifts use LPG fuel; the remaining forklifts are diesel powered. Likewise, at the Port of Los Angeles, the container terminals totaled 46 forklifts, 4 (9%) of the forklifts use LPG fuel. Total forklifts at POLB dry and break bulk terminals was 153 forklifts. LPG fuel was used in 37 (24%) forklifts, instead of diesel fuel. At the POLA, a majority (78%) of the forklifts are using LPG instead of diesel or gasoline. (Starcrest, 2004a) (Starcrest, 2004b)

Raley's has been successfully using LNG yard tractors for 8 years. According to a Raley's representative, the LNG yard tractors work fine compared to the diesel tractors. The drivers have commented the engine produces less soot and smell. Because of the higher cost of running LNG engines and the current and future cleaner emitting diesels, the future of the LNG fleet at Raley's does not look promising. Higher cost fuel, for example, is costing about $2.25 for diesel and about $4.00 for LNG equivalent. Another high cost is spark plug replacement, costing each engine $28 per cylinder every 25,000 to 35,000 miles. (ARB, 2005a)

Von's grocery, responding to a NRDC lawsuit, is using LNG yard tractors at their distribution center. A Von's representative stated the drivers do not seem to notice between the LNG and the diesel trucks, other than refueling the LNG more often. One point is the higher cost of the fuel, about 20% higher for LNG than diesel fuel. (ARB 2005b)

Port of Virginia is currently using new "hybrid" straddle carriers. The hybrid technology is new to straddle carriers. Common straddle carriers are powered by diesel engines powering hydraulics for motion and lifts. New hybrid technology straddle carriers enlist the use of a diesel-electric drive, the same technology that has been used by rubber tired gentry cranes in use in California. According to a supervisor at the Port of Virginia, the new "hybrid" straddle carriers are working just fine. (ARB, 2005e)

The Port of Long Beach (POLB) will be conducting a pilot project to evaluate LNG feasibility on some cargo handling equipment. The LNG equipment will be compared to the standard diesel equipment to meet the port needs and future emission standards. Currently, the POLB has ordered LNG yard trucks and is awaiting delivery. (POLB, 2005)

E. Fuel Cost

Table F-5 compares standard fuel prices to alternate fuel prices. Gasoline and diesel prices shown are retail prices. The prices include federal, state, and local taxes. The prices are listed as gasoline gallon equivalent.

Table F-5
Alternative Fuel Price / Gallon Comparison

Fuel	Week of 11/15/04	Week of 3/21/05
Gasoline	2.22	2.56
Diesel	2.27	2.47
CNG*	1.82	1.56
Propane*	2.33	1.63

*Price gasoline gallon equivalent (All West Coast Prices)
(Clean Cities, 2005)

Table F-6 below outlines various fuels and its energy content relative to gasoline.

Table F-6
Gasoline Gallon Equivalency Table

Fuel	Unit	BTU's	Gal. Equivalent
Gasoline	Gallon	114,100	1.00
Gasoline (RFG)	Gallon	112,000	1.02
Diesel	Gallon	129,800	0.88
LNG	Gallon	75,000	1.52
CNG	Cubic Foot	900	126.67 cu. ft.
LPG	Gallon	84,300	1.35

Soy Power, 2005

Although at present natural gas is less expensive than diesel, it is impossible to be certain about fossil fuel market conditions between now and 2020. In recent years, CNG has been 15 – 20 percent more expensive (on a $/mile basis) compared to diesel. However, key parameters of the natural gas market appear to be changing. Canadian imports, which have met domestic demand growth in the past 10 – 15 years, are becoming insufficient. In addition, environmental concerns continue to favor natural gas combustion over oil and coal, and demand for cleaner fuels may well push natural gas prices higher. (ARB, 2005g)

F. Fueling Infrastructure Cost

Gasoline and diesel fuel terminals are commonly located at or very near ports. Thus, the fueling infrastructure already exists. The same is not true for alternative fuels. As a result, using an alternative fuel will result in infrastructure costs not associated with diesel or gasoline.

The recent analysis, prepared by ARB regarding the South Coast transit bus rule, identified the cost of construction of an L/CNG (gasification) station at about $25,000 per bus and for a CNG (compression) station at about $36,000 per bus.

In 1998, Raley’s constructed a permanent 13,000 gallon LNG fueling station at an estimated cost of $350,000. This station fueled eight heavy-duty on-road trucks and two yard tractors. A current completed LNG terminal, dispensing about 16,000 gallons from a single point will cost about $700,000. This terminal would refuel about 30-35 vehicles. Costs for a permanent alternative fueling site can vary widely. (ARB, 2005a) (Raley's, 2000) (Clean Car Maps, 2005) (ARB, 2005f) (ARB, 2005g)

G. Equipment Cost

Alternative fuel engines are more expensive to purchase than their diesel counterparts. ARB staff estimated that the costs of a LNG yard truck is currently about $40,000 per truck more than its diesel counterpart. In collection vehicle application, ARB staff estimated that the incremental cost of a collection vehicle is $50,000 more than a diesel equipped vehicle.

Another source of information on the cost of alternative fuel equipment is the Carl Moyer Program. Since 1998 there have been 23 projects for yard hustlers operating in California, most in port areas. All of the projects replaced diesel engines with liquefied natural gas engines. The engines were 195 or 200 horsepower engines. The chart below lists the incremental cost increase of a LNG engine compared to a similar diesel engine. (Carl Moyer)

Table F-7
LNG Compared to Diesel
Incremental Cost per Unit

Year	Quantity	Incremental Cost
1998 - 1999	12	$9,630 - $20,000
2001 - 2002	1	$19,499
2002 - 2003	10	$29,128

H. Maintenance and Repair Costs

Based on current experiences with natural gas buses and collection vehicles, ARB staff believes that maintenance costs for alternative fueled equipment will be somewhat higher than for diesel equipment. For example, staff estimated the extra maintenance cost for natural gas buses to be $4,300 per year and $2,000 per year for collection vehicles. Additional costs would also occur due to maintenance of the fueling facility.

I. Other Technologies

Dual Fuel: Dual fuel engines are compression ignition engines that use diesel fuel and a supplementary fuel. The supplementary fuel is usually natural gas, but propane and even methanol can be used. They operate very similarly to diesel engines and they may operate on a wide percentage of diesel fuel, ranging from 100% diesel to as little as 1%. Many older dual fuel engines obtained about 5% of their energy from diesel fuel, but newer pre-chamber dual fuel engines may use as little as 1%. An advantage of dual fuel engines is that they can attain higher efficiencies than spark ignition engines (CI engines are more efficient than SI engines), but they have lower emissions than diesel engines.

A diesel engine cannot be used if alternative fuel is only being used. An alternative fueled engine needs a spark ignition to ignite the fuel. Manufacturers use diesel engines as a base to burn alternative fuel. The diesel engines have been modified to accomplish a spark ignition instead of a compression ignition, lower compression ratio, and air and fuel mixture combined prior to entering the combustion chamber, comparable to an Otto cycle engine.

J. Conclusions

Alternative fuel use in cargo handling equipment has been successful on limited equipment applications. However, high fuel and infrastructure cost, new cleaner emitting diesel engines, and small number of engines available make alternative fuel a limited option. Yard trucks and forklifts have been successfully using alternative fuel. However, the use of 2007 on-road engines in yard trucks greatly narrows the emissions reduction advantage of alternative fuels compared to diesel for this application. Additional alternative fuel projects involving other cargo handling equipment (i.e., top handlers, RTG cranes, etc.) will need to take place before a full port or rail yard can use alternative fuel for all applications. The possible higher cost of the alternative fuel and alternative fuel infrastructure, along with cleaner diesel engines which are near to the emissions of alternative fuel engines, favors selection of alternative fuels on a case-by-case basis instead of a general mandate.

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