PennState College of Engineering

GE Transportation

# GE Transportation

## Freight, Fuel, & Emissions

**Introduction to Engineering Design**
**EDGSN 100 Section 102**

**007 / Design team # 7**


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**Date: 12/11/2015**

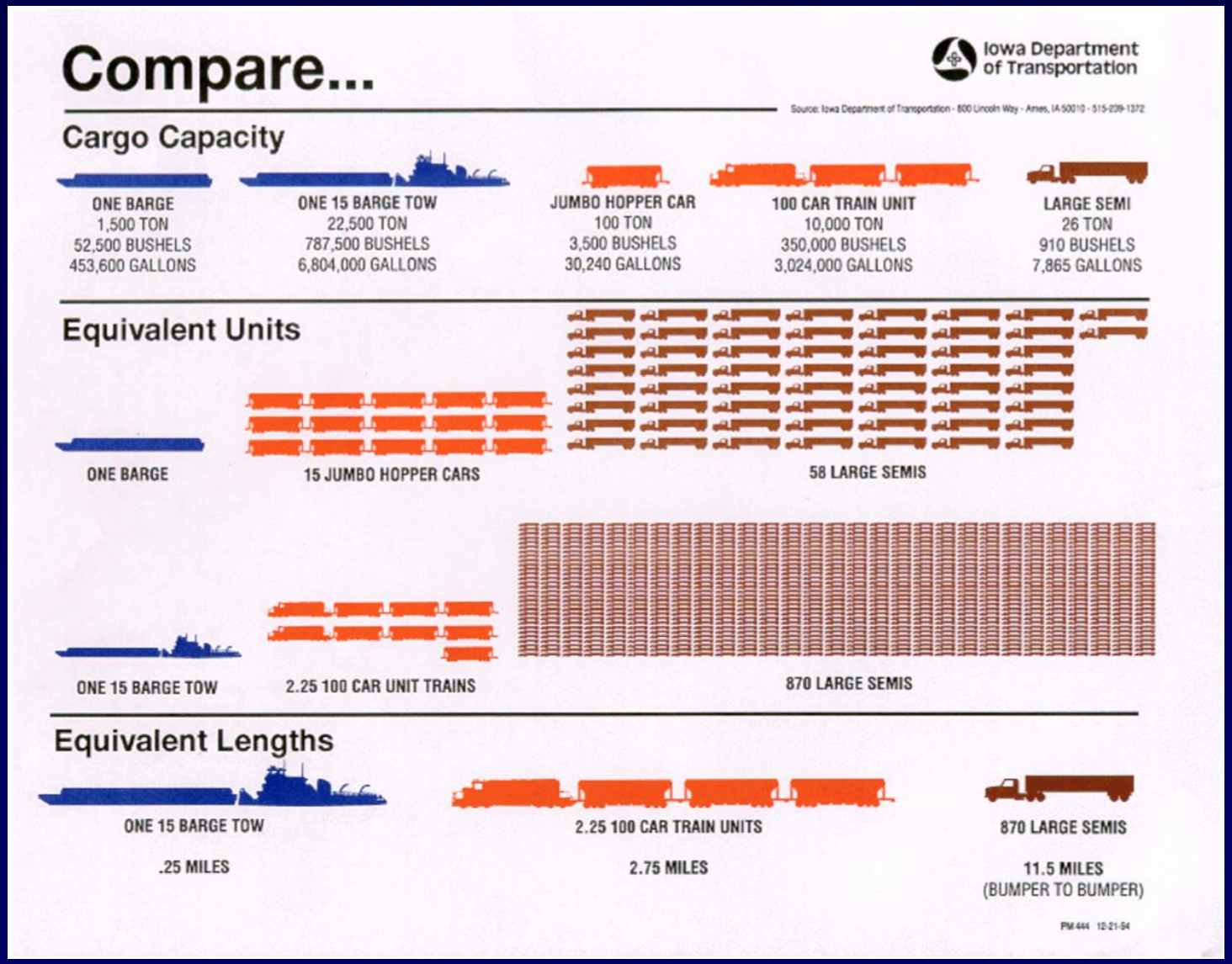
# Introduction

The Engineering Design Team 007 has been assigned by GE Transportation to manage locomotive fleet of the city of Pittsadelphia. The fleet currently is composed of 50 tier 2 locomotives, which will be required be replaced with tier 3 or higher upon their failure. The city is also experiencing smog from the exhaust of these locomotives, specifically the chemical NOx, and this problem should be solved as well without affecting the freight import and export of the city.

# Transportation Infrastructure Condition and Capacity

| | Condition | Capacity |
|---|---|---|
| Roads and Bridges | 23% of state owned roadways are rated poor. | The capacity of one large semi truck is 26 tons/ 910 bushels/ 7865 gallons. |
| Inland Water Ways | According to the USACE Pittsburgh District Dam Safety Team, most of them are rated as fair and poor, some are unsatisfactory. | The capacity of each barge is 1500 tons/ 52500 bushels/ 453600 gallons. |
| Freight Rail System | Rated fair. | the capacity of one rail car is 100 tons/ 3500 bushels/ 30240 gallons. |

# Standard Capacity for Alternate Transportation Modes



# Transportation Costs and Concept of Operations (ConOps)

| | Cost (per ton-mile) | Advantages | Disadvantages |
|---|---|---|---|
| Trucks | 17.0 cents | Can get to anywhere. | Too expensive, need more drivers and costs more. |
| Barges | 2.0 cents | Cheap, carries more. | Depends on weather, needs to use other transportation. |
| Railroads | 3.0 cents | No traffic lights, high-speed, safe | unsafe for fragile items, unsuitable for short distance. |

Conclusion: Railroads is the best solution compared to others.

# EPA Diesel Emission Standards

Tier 0-2 standards are met through engine design methods, without the use of exhaust gas aftertreatment.

Tier 3 standards, to be met by engine design methods.

Tier 4 standards, which are expected to require exhaust gas aftertreatment technologies.

# Line-Haul Locomotive Emission Standards, g/bhp*hr

| Tier | MY | Date | HC | CO | NOx | PM |
|---|---|---|---|---|---|---|
| Tier 0[a] | 1973-1992[c] | 2010[d] | 1.00 | 5.0 | 8.0 | 0.22 |
| Tier 1[a] | 1993[c]-2004 | 2010[d] | 0.55 | 2.2 | 7.4 | 0.22 |
| Tier 2[a] | 2005-2011 | 2010[d] | 0.30 | 1.5 | 5.5 | 0.10[e] |
| Tier 3[b] | 2012-2014 | 2012 | 0.30 | 1.5 | 5.5 | 0.10 |
| Tier 4 | 2015 or later | 2015 | 0.14[f] | 1.5 | 1.3[f] | 0.03 |

a - Tier 0-2 line-haul locomotives must also meet switch standards of the same tier.
b - Tier 3 line-haul locomotives must also meet Tier 2 switch standards.
c - 1993-2001 locomotive that were not equipped with an intake air coolant system are subject to Tier 0 rather than Tier 1 standards.
d - As early as 2008 if approved engine upgrade kits become available.
e - 0.20 g/bhp-hr until January 1, 2013 (with some exceptions).
f - Manufacturers may elect to meet a combined NOx+HC standard of 1.4 g/bhp-hr.

Line-haul locomotives are powered by an engine with a maximum rated power (or a combination of engines having a total rated power) greater than 2300 hp.

# Switch Locomotive Emission Standards, g/bhp*hr

| Tier | MY | Date | HC | CO | NOx | PM |
|---|---|---|---|---|---|---|
| Tier 0 | 1973-2001 | 2010[b] | 2.10 | 8.0 | 11.8 | 0.26 |
| Tier 1[a] | 2002-2004 | 2010[b] | 1.20 | 2.5 | 11.0 | 0.26 |
| Tier 2[a] | 2005-2010 | 2010[b] | 0.60 | 2.4 | 8.1 | 0.13[c] |
| Tier 3 | 2011-2014 | 2011 | 0.60 | 2.4 | 5.0 | 0.10 |
| Tier 4 | 2015 or later | 2015 | 0.14[d] | 2.4 | 1.3[d] | 0.03 |

a - Tier 1-2 switch locomotives must also meet line-haul standards of the same tier.
b - As early as 2008 if approved engine upgrade kits become available.
c - 0.24 g/bhp-hr until January 1, 2013 (with some exceptions).
d - Manufacturers may elect to meet a combined NOx+HC standard of 1.3 g/bhp-hr.

Switch locomotives are powered by an engine with a maximum rated power (or a combination of engines having a total rated power) of 2300 hp or less.

# Diesel Engine Exhaust Emissions (DEEE)

## Diesel Emission Chemistry

a. **NOx**
   i. Nitrogen + Oxygen (combustion)
   ii. Cities have high NOx emission (air pollution, photochemical smog)

b. **Particulate Matter (PM)**
   i. fine particles (e.g. soot) produced in spark ignition of engines
   ii. Health concerns with heart and lung cancer, and mental functioning

c. **CO2**
   i. CO2 and CO make up the main components of gas in diesel engines.
   ii. greenhouse gas = contributes to pollution and global warming

d. **Hydrocarbons (HC)**
   i. operation of engines in enclosed spaces (underground mines, buildings, tunnels) can cause headaches, dizziness, and lethargy.
   ii. major contributor to the smell of diesel.
   iii. causes smog

# Diesel Engine Exhaust Emissions (DEEE)

## Diesel Emission Reduction Strategies

**Engines Modification**

a. *Homogenous Charge Compression Ignition (HCCI)*

   i. *Solves Trade off with NOx-PM*
   ii. *fuel → heated air cylinder→ greater mixing of air and fuel→ enhanced mixing prevents PM rich formation→ cylinder compresses→ multiple ignitions→ lower peak flame temp. → reduces NOx emissions*

Exhaust Control Technologies

a. a. *Diesel Particulate Filters (DPFs)*

   i. *captures soluble organics and PM*
   ii. *often made of ceramic monoliths or woven fibers*

# Alternate Fuels

a. **Biodiesel (BD)**
   i. derived from liquid feedstock (vegetable oils,animal fats, soybeans).
   ii. Contains high oxygen content→ virtually no sulfur or aromatics→ PM reduction

Bio Diesel

a. **Dimethyl Ether (DME)**
   i. derived from carbonaceous feedstock (natural gas, coal, renewable biomass)
   ii. partically oxidized→ virtually no sulfur and aromatic gas→ PM reduction

DME

# Locomotive Fleet Upgrade

- Locomotives will be replaced with tier 4 at the end of their minimum useful life
- Groups C and D equipped with Exhaust Aftertreatment Systems
- Groups A and B upgraded to tier 3

# Summary

- Upon reaching their minimum useful life, locomotives should be either sold or replaced with Tier 4 rather than Tier 3. This small price difference different in the NOx emission. The smog problem in Pittsadelphia will be greatly diminished by this reduction in NOx emissions, which will please the public.

- The replacement of Tier 2 locomotives will be spread over a few years because how heavy they are and fast they reach the end of their useful life.

- the current 50 Tier 2 locomotives, groups C and D will be equipped with after-treatment (100K each), as a temporary solution to reduce NOx emissions.

## Summary

- Assuming that the rails in Pittsadelphia are at least Class 3, meaning the trains can travel at 40 mph22, group C locomotives (with 300,000 miles already) will need 4 aftertreatment systems each and group D (with 450,000 miles already) will need 3 aftertreatment systems each before they read 750,000 miles and are replaced with new locomotives

- The 20 locomotives in groups A and B will be upgraded from tier 2 to tier 3 for $750K each for $15M. This be the only part of the solution to be implemented immediately.

# Closing

Our solution will cost a total of $222M upon completion, but the majority of the process will occur gradually and the cost will be spread out as well.