Locomotive Auxiliary Power Units

Larry Biess
DIrector, CSX Transportation Advanced Engineering

Before we begin:

A man who carries a cat by the tail learns something he can learn in no other way. ~Mark Twain

Five Steps of Lean:

1. Specify value (this is defined by the end user or customer)
2. Identify the value stream (understand what we do and why)
   - Identify behaviors or activities that add value
   - Identify activities that do not add value and which can be eliminated
   - Identify activities that do not add value and which cannot be eliminated
3. Flow: Get the process to work in an uninterrupted manner
4. Pull: Respond to the customer demand, provide service or use resources only when called upon by the customer
5. Perfection: Optimize and learn, repeat

Locomotive Operations: Value, Step 1

- Locomotives provide value when they are used to pull freight.
  - When they are sitting still (idling) they are not creating value.
    - Some idling can be eliminated
    - Some idling cannot be eliminated
- Implicit goal: only operate main engines to pull freight.

Behavior that does not add value Step 2

How much do locomotives idle?

EPA weighted duty cycle:

- Switcher (<2250hp) 56%
- Road (>2250hp) 38%

CSX data:

- Switcher 58- 66%
- Road 42%

Understanding Existing Behavior: Step 2

- Practical
  - Freeze Protection
  - Battery Charge
  - Air Conditioning
  - Avoid Terminal Brake Test (60# @EOT)
- Cultural
  - Starting Reliability (Fear of Restart Failure)
  - Ownership and Accountability
  - Perceived futility of act of shutdown
  - Ingrained operating habits

Idling Costs and Effects
Step 2

What can we save in fuel if idle is reduced?

- On 2629 fuel savings were estimated at 14,800 gallons per year.
- CSX estimates aggregate fuel savings for:
  - Switcher @10,700 gallons per year
  - Road @12,000 gallons per year
- Based on CSX derived availabilities and fuel rates, and assuming an 80% reduction in idle time.
- Based on 2629 experience with voluntary shutdowns.
- CSX assumed 8,000 gallons a year when project was evaluated.

Crew Interview: Flow, Step 3

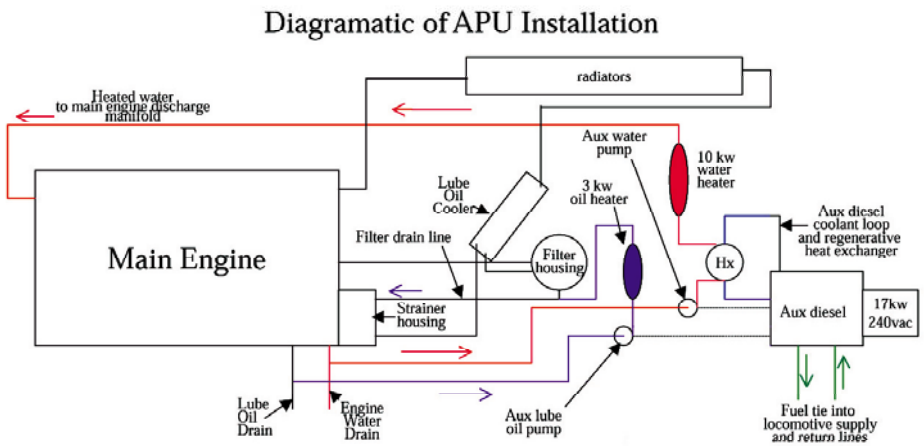
- The system must be easy to use and understand.
- Minimum change to operating rules.
- Want “get in and go” reliability.
- Forced shutdowns were acceptable as long as there was an audible warning and a way to override.
- Since they were a yard unit, they felt they did not need shutdown air.
- Wanted air conditioning in cab.
- Shutdowns would not be fought if crew comfort and radio/htd was maintained.
- Manual restart from the engine start station was acceptable.
- Shutdown time was to be 30 minutes.
- Manual starting of the APU for crew comfort was acceptable
- APU start for locomotive system maintenance (freeze protection) should be automatic.

Inception of Idle Reduction System, Step 3

- Excess capacity to permit future leverage for a variety of uses.
- High level of automation to permit auxiliary diesel engine start and shutdown in response to any number of inputs.
- A main engine shutdown timer to shut the main engine down after 30 minutes.
- Two hour APU run if operator initiated start.
- Idle timer warning to alert crew of an impending shutdown.
- Rugged, extremely reliable, low maintenance.,
- Use of alerter reset button to silence the alarm and reset the idle time.
- Isolate the locomotive batteries automatically from all loads, except the radio and HTD.
- The auxiliary engine must be able to provide maximum output with the main engine operating at peak horsepower.
- Electrical distribution system equipped with relay logic to prevent simultaneous operation of unrelated loads.
- Automatic load prioritization.

Building the APU: CSXT 2629

November 1999 CSXT's Cumberland Locomotive Shop released a modified GP38-2; CSXT 2629.



The APU: CSXT 2629
Step 3

2629 Equipment:

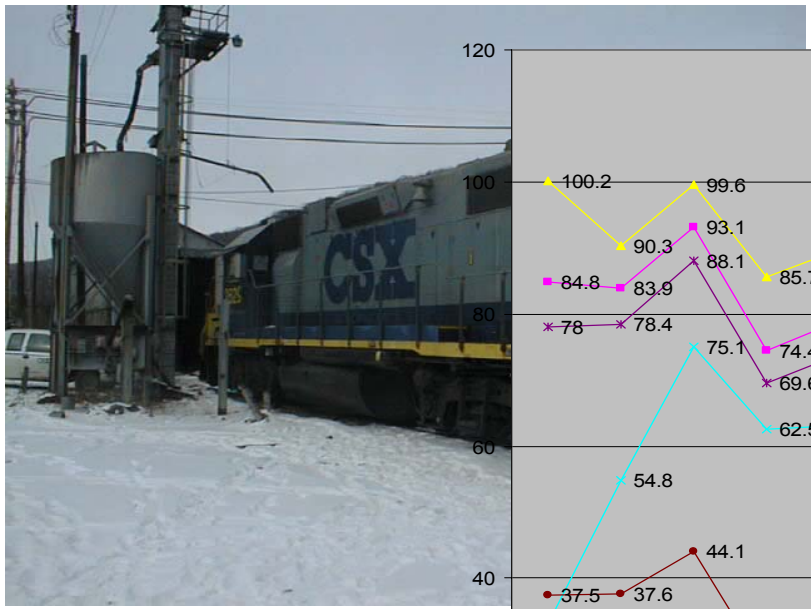
- **17kva auxiliary generator, 240/120vac, single phase**
- **9kw of available water heat**
- **6kw of available oil heat**
- **cooling water thermostat**
- **120 volt lighting**
- **240vac heaters (3kw) for toilet compartment**
- **240vac/70vdc battery charger**
- **exterior floodlights, motion sensitive**
- **interior florescent lights, motion sensitive**
- **36,000 btu 240vac air conditioner**
- **120vac outlets in engine room and cab**

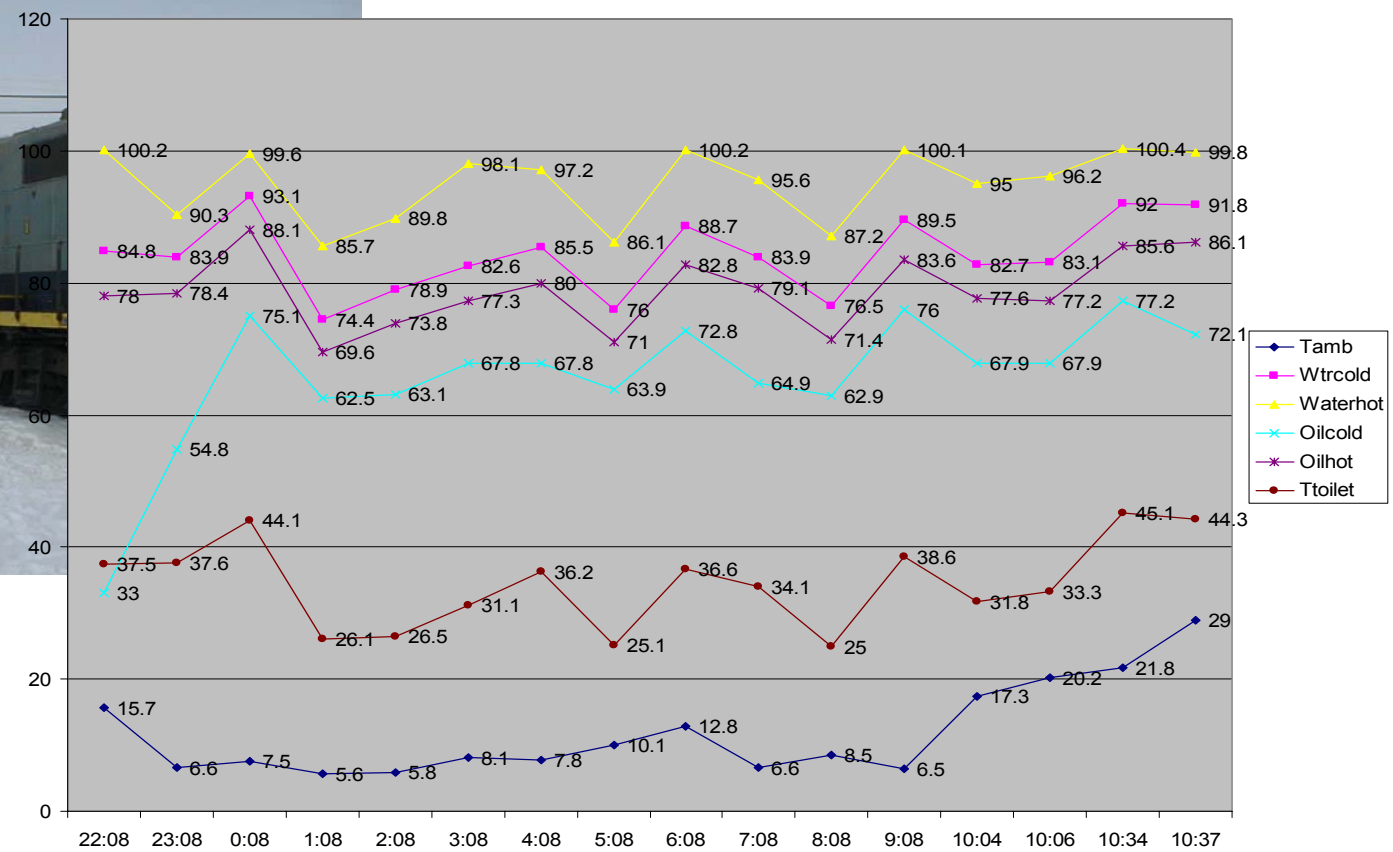
The New Operating process, Step 3

- The Crew was given a tour of the new locomotive and training on the new system, with emphasis on the fact that the system was developed with their input.
- The crew was told to operate the locomotive in accordance with current operating rules and the crew was expected to comply with same.
- The system would shut the locomotive down automatically.
- The crew was invited to shut the locomotive down consistent with the CSX fuel conservation policy, which is to keep the unit idling if the temperature is expected to drop to less than 40 degrees F.
- The crew was given a demonstration of the air conditioner and crew comfort appliances and was told that as long as they did not disable the system these appliances would be available.
- Decals explaining all of the operating characteristics, with instructions and phone numbers, were applied to the locomotive and APU.

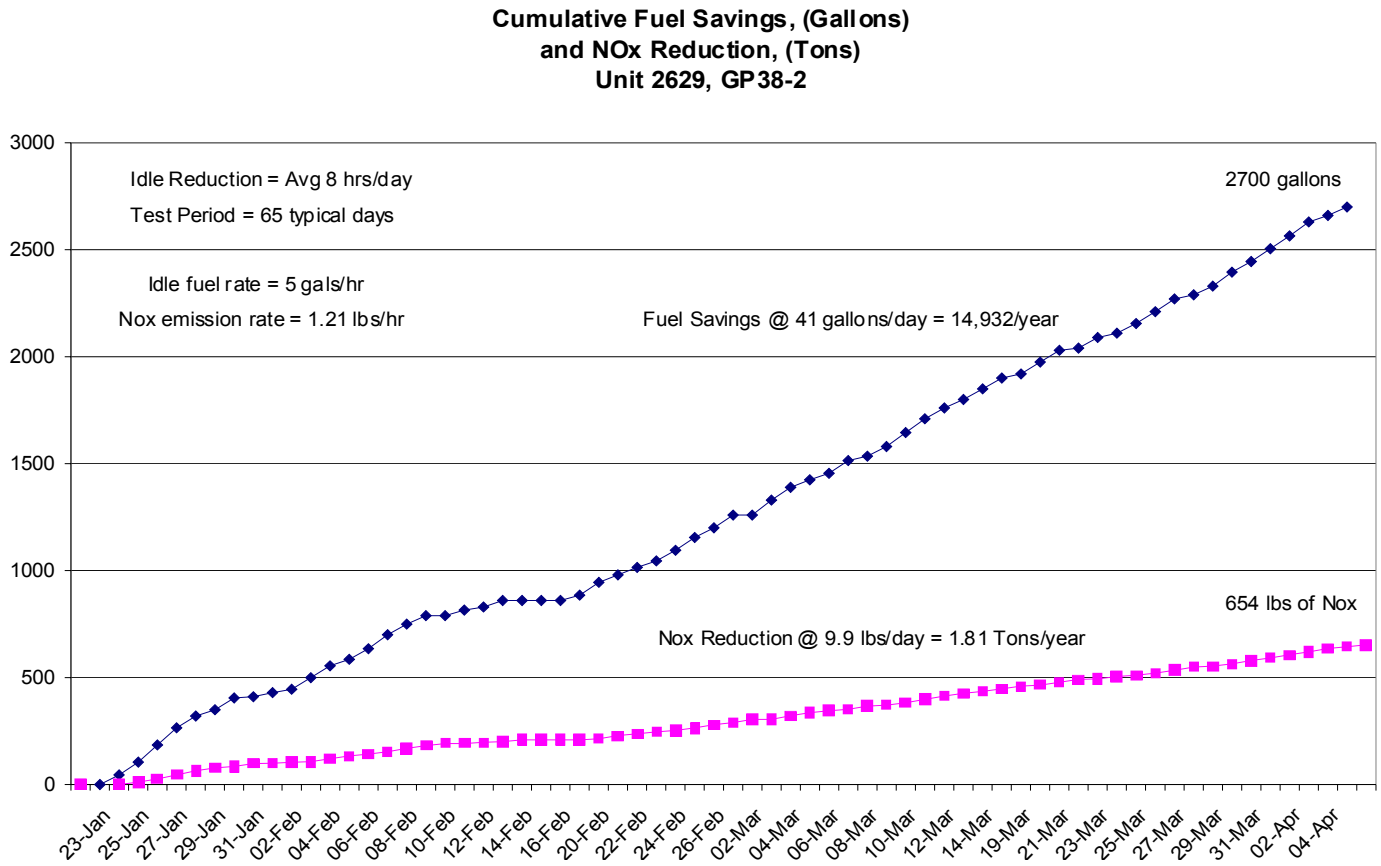
Results
Step 3

System Performance, winter 1999/2000:





Idle Reduction Effects
Step 3



CSXT 2629 Today

- >5,000 hours of run time
- Lowest recorded ambient temperature: -5 degrees F.
- Maintained coolant temperature during this ambient: 80 degrees F
- Maintained lube oil temperature during this ambient: 50 degrees F
- Cycle time during this ambient: one hour on, one hour off
- Estimated 14,000 gallons fuel savings per year.
- Air conditioner was repaired for a bad contactor 29 months ago. Since this last repair the unit has functioned without incident.
- APU has been shopped for hose leaks, broken mounting bolts, low lube oil shutdowns, and oil and water leaks from the heater tank. Each of these issues was corrected by the use of a new design or the use of new material.
- The APU oil and water filter have been replaced once, no other maintenance has been performed.

2629 Crew Feedback, 2002
Pull and Perfect, Steps 4 and 5:

- The crew was recently interviewed about the performance of the APU and operating issues with the new system, and they state that they like the new system:
  - The crew does not use the interior or exterior 120vac lighting.
  - The crew does use the 120vac outlet in the cab.
  - Crew enjoys the air conditioning, and quickly notifies Mechanical forces if the APU malfunctions because of loss of air conditioning..
  - The engine shutdown timer shuts locomotive down automatically during warm and cold months.
  - The crew has accepted the shutdown timer and reset.
  - The crew does not take issue with restarting the locomotive.
  - Although reluctant to allow the locomotive to shutdown during the coldest winter nights, they have gotten confident in the ability of the APU to maintain locomotive battery charge and system temperatures to provide a reliable main engine start.

2629 Headaches: Perfect, Step 5

- Recurring calls on "Engine Shutting Down" when locomotive is on the line of road and used by unfamiliar crewmembers.
- Oil and water leaks from APU.
- Setup and operator error.
- Periodic introduction of a new crewmembers. Inevitably, these workers learned through trial and error (and from more senior crewmembers) how the system behaved. Familiarity and training would be a recurring issue during the subsequent CSX rollout.
- Dead APU batteries.
- Out of fuel.
- Oil recirculation system failures.
- New machine, new parts, new maintenance items.

Rollout…

A committee is a cul-de-sac down which ideas are lured and then quietly strangled. ~Barnett Cocks, attributed

The APU: Latest Iteration

- System was integrated with a main engine stop/start device and computer, providing more exquisite control and system redundancy,.
- System integration added a lot of work and complexity to the APU.
- Air compressors were added to six axle locomotives, and then removed.
- Locomotive operators were not as involved in latest design, and they let us know.
- Air conditioning and cab heat were not addressed (at first) and we are now moving to add heat for the cab.
- Shutdown time was initially set to less than 30 minutes (can be as low as 10) to maximize idle savings…and crew irritation
- Utilization was only 40% (and this during the summer).
- Crews resisted use of system, citing complexity, reliability, and aggravation.

Draining the Swamp, Locomotive Condition:

- New operating behavior, especially frequent starts and stops, has uncovered pre-existing conditions such as:
  - Defective batteries
  - Defective charging systems
  - Defective Engine Protection Devices
  - Defective/weak starters
  - Installation errors

Draining the Swamp, Locomotive Operating Practices:

- New operating behavior has uncovered new constraints and circumstances which require system revisions:
  - Idling unattended on the main line
    - Need lights on lead unit and trail unit.
  - Adherence to operating policy
    - Air and the Power Brake Rule
    - Do we tie down unattended trains as consistently as we say we do?
    - Idle time less than 30 minutes is creating some aggravation.
  - Simpler is better
    - Any change in the cab environment can cause problems.
    - Cab informational decals do not solve training problems.
    - Autostart of the main engine is not completely understood by crews and is probably not a good idea on an old mechanically injected engine.

Lessons Learned:

- Carefully define idling that can be eliminated and idling that cannot be eliminated (yet).
  - Air
  - Crew comfort
  - Regulatory requirements
  - Operational aggravation
- Understand your operating habits. Look beyond written policy to determine true operating behavior and needs.
- Keep it simple and minimize the amount of impact the system will have on existing operating practices. Resist the temptation to over-design.

Lessons Learned (cont):

- The most important stakeholder is the locomotive operator.
  - Involve the locomotive operators in the design process and build to their requirements.
  - Seek out opinion leaders.
  - Give them a stake in it.
  - Change behavior by sharing the rewards.
- Be prepared to discover pre-existing conditions which may be exposed under the new operating process and be prepared to deal with them.
- Understand that maximizing operational efficiency is not a point, it is a process. It will take time to change forty of fifty years of operating habits.

Incentives

- Incentives matter, and you get what you measure.
- Projects that save money have low sex-appeal.
- To get people to install APUs, and then to *maintain them* periodic incentives may be necessary.

Coase said:

- If there is ownership
- And the ability to trade then:
- Resources will be managed efficiently.

Without these, resources are wasted and eventually ruined

A suggestion on how to change behavior and get cleaner air

- Cap and Trade
  - Enforce Tier limits on all engine families assuming existing duty cycle.
  - Allow other emission reduction technologies to earn credits for over compliance with Tier at the expense of those who either cannot or will not meet Tier.
  - Allow mobile sources to trade credits with stationary sources and other mobile sources.
  - To tighten the market, wait for technology to mature and then lower the Tier limits.
- Create a competitive, innovative environment where firms see being “clean” as a competive advantage.

Thank You…

Rail Fans (FRN's) in Cumberland had a religious experience when 2629 departed the terminal with added running lights.

Appendix

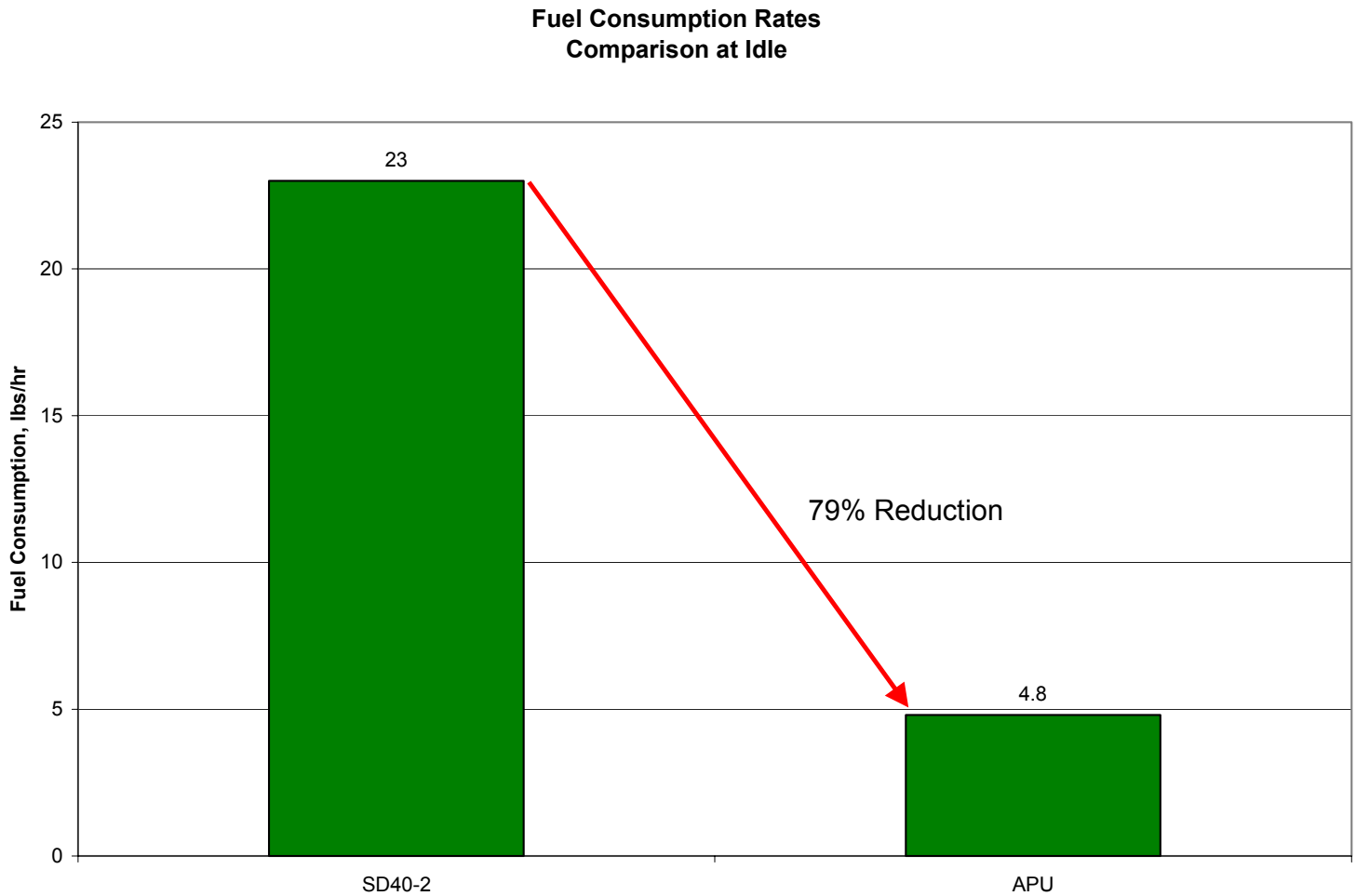
Reduction results from 2629

The APU: Kubota Engine

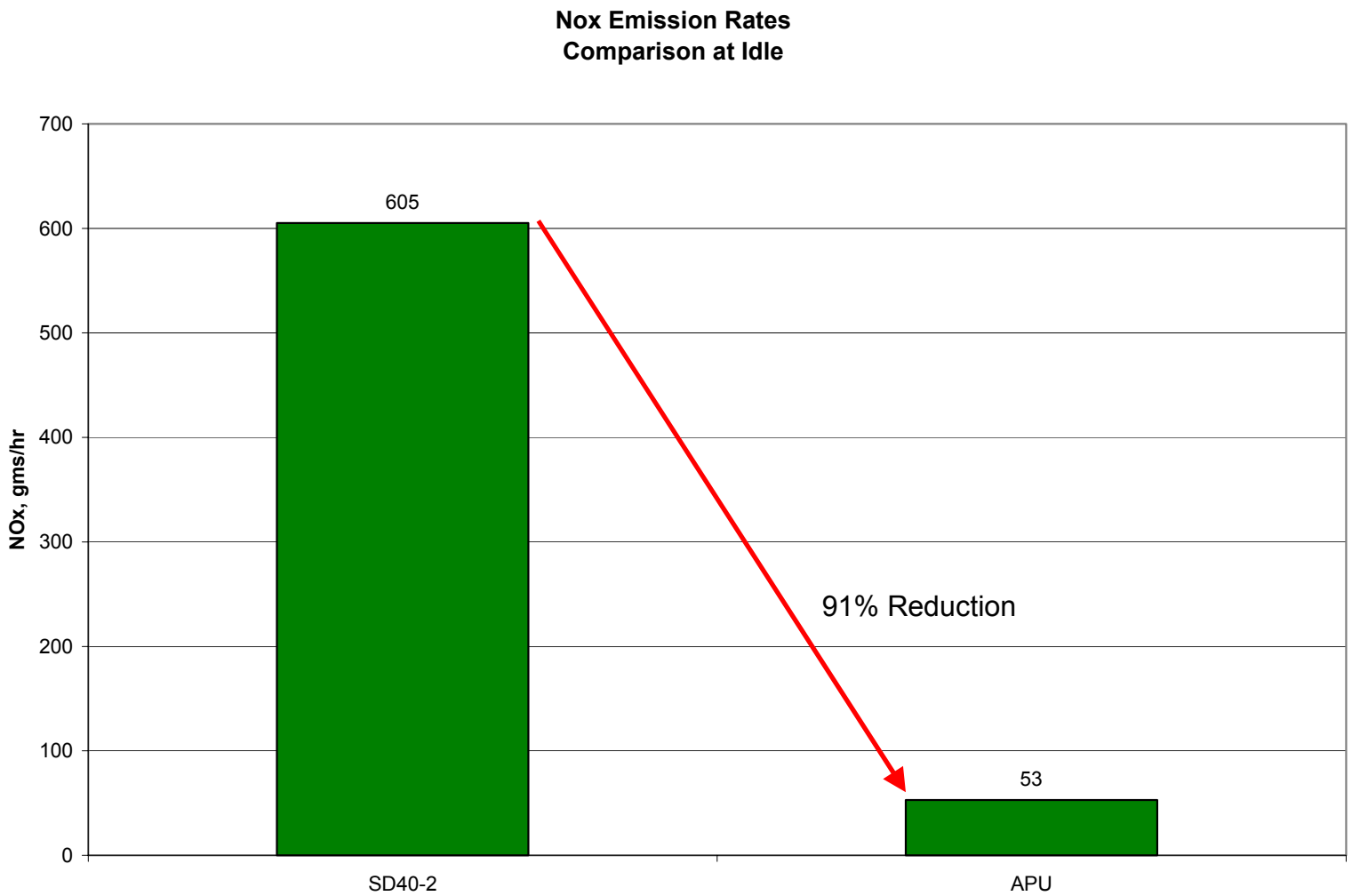
Turbocharged, mechanically injected engine.

- **Rated at 48 continuous horsepower at 2800 rpm.**
- **Synchronous speed is 1800 rpm, continuous horsepower rating is 34 horsepower.**
- **Maximum load (including air compressor) is about 27 horsepower.**
- **Oil change and maintenance occur at two year intervals.**
- **Easily repaired 12vdc starting system.**

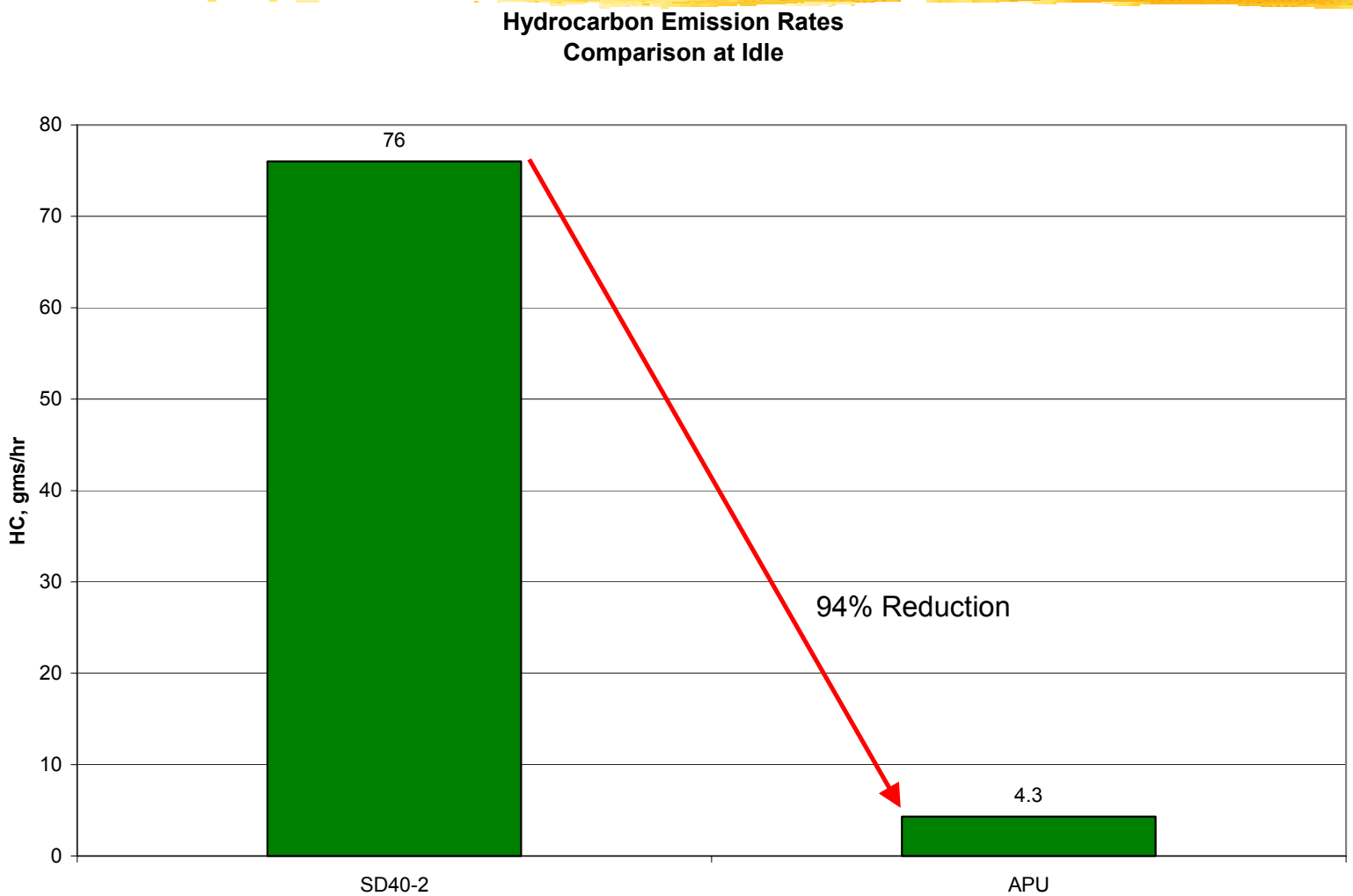
Idle Reduction Effects



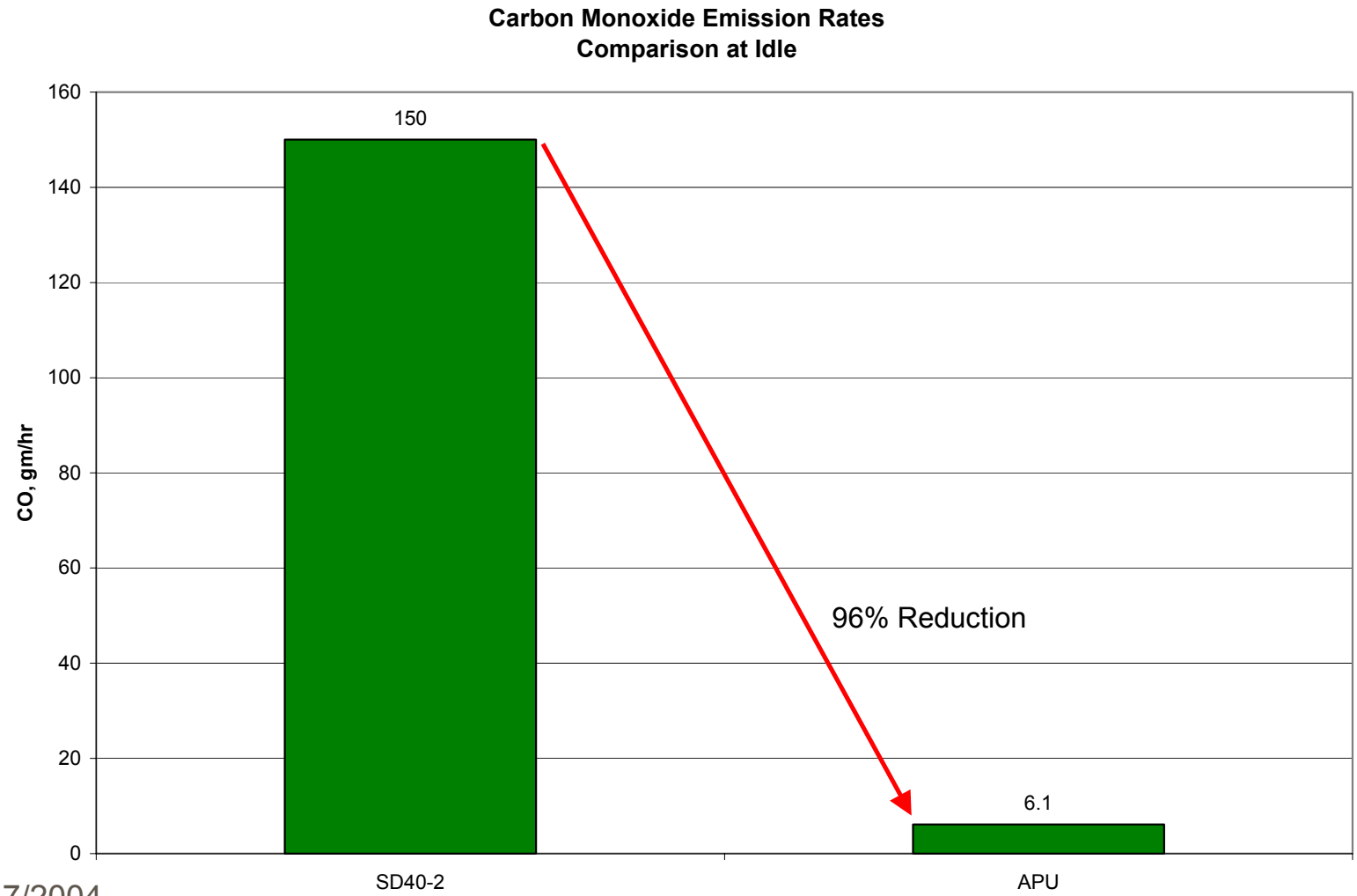
Idle Reduction Effects



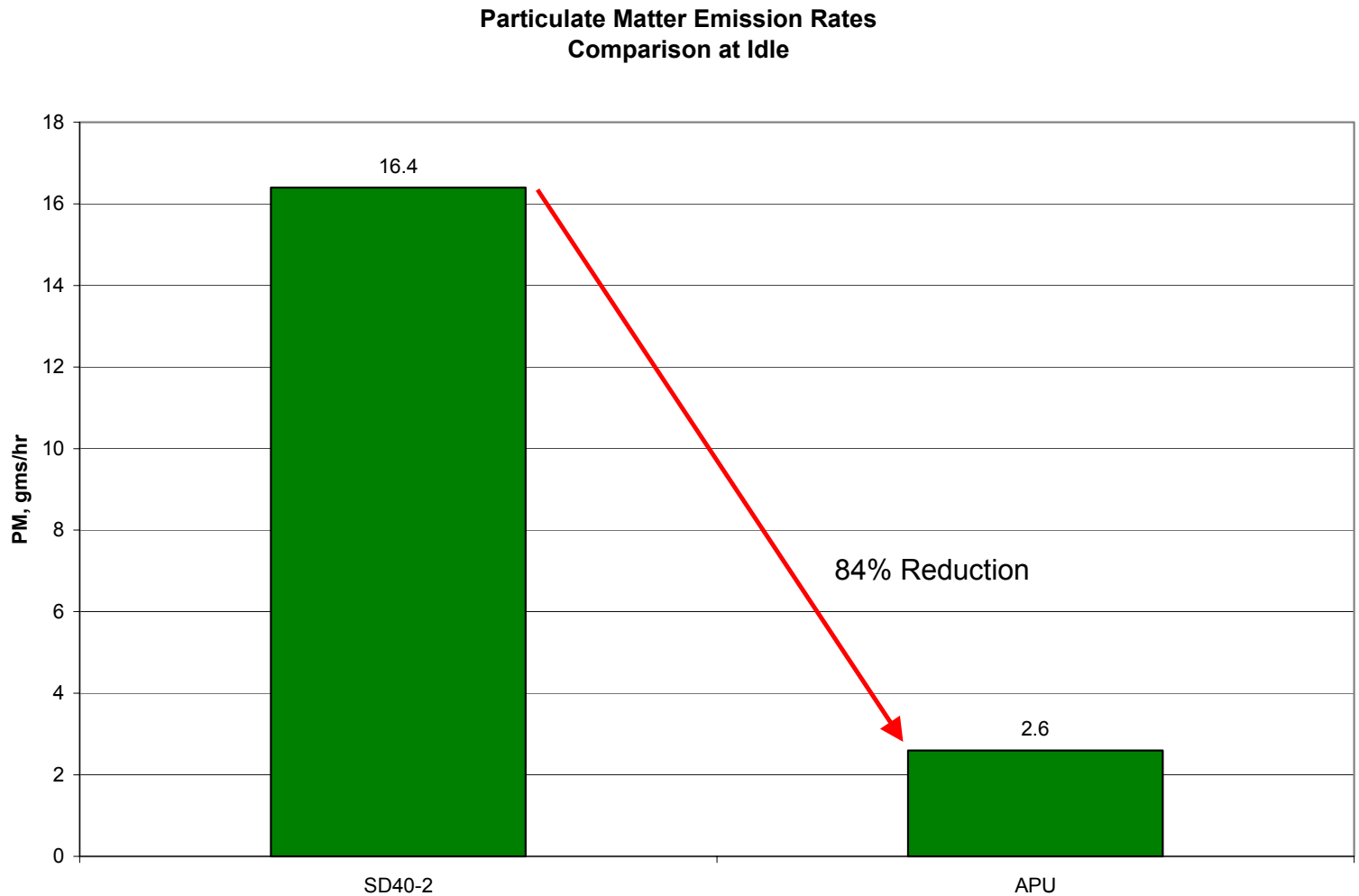
Idle Reduction Effects



Idle Reduction Effects



Idle Reduction Effects



Beyond Fuel and Emissions

- Noise levels are markedly lower with the APU:

Distance	Locomotive Shut Down	Idle	High Idle Notch 3	APU Unloaded	APU Loaded
100 Ft. Forward	42.0-45.0 / 44.0	55.5 - 56.5	65.0-66.0 / 65.8	47.0-48.5 / 48.0*	49.5-51.5 / 51.0
150 Ft. Forward	42.0-45.0 / 44.0	53.5 - 54.5	63.0-64.5 / 64.0	49.0-50.5 / *	45.5-47.0 / 46.8
100 Ft. Crew Side	40.0-55.0 / 48.0***	64.0 - 66.0	71.0-73.0 / 72.5	54.0-56.0 / 55.0**	55.0-57.0 / 56.0
150 Ft. Crew Side	41.0-50.0 / 48.0	59.0 - 61.0	67.0-68.5 / 68.0	51.5-53.5 / 53.0	51.0-55.0 / 54.0
100 Ft. Rearward	40.0-45.0 / 44.0	57.0 - 58.5	67.0-68.0 / 67.5	47.5-49.0 / 48.5	49.5-51.0 / 50.5
150 Ft. Rearward	38.0-44.0 / 42.0	54.0 - 55.0	64.0-65.0 / 64.5	44.5-45.5 / 45.0	47.0-48.5 / 48.0
100 Ft. Engineer Side	42.0-46.0 / 45.0	62.0 - 63.0	72.0-73.0 / 72.5	49.5-51.0 / 50.5	50.5-52.0 / 51.8
150 Ft. Engineer Side	42.0-45.0 / 44.0	57.5 - 58.5	67.5-68.5 / 68.0	46.0-47.5 / 47.0	48.0-49.0 / 48.5