



Tier 5 Rulemaking Workshop II

Certification Amendments

October 30-31, 2023

Outline

- Overview of Certification Amendments
- Averaging, Banking, and Trading (ABT)
- New Replacement Engine Provisions and Mandatory Reporting for Rebuilt Engines
- Diesel Aftertreatment Accelerated Aging Cycle (DAAAC)
- Infrequent Regeneration Adjustment Factor (IRAF) Considerations and Preconditioning

Overview of Certification Amendments



Overview: Proposed Certification Amendments

(1 of 2)

- California-specific averaging, banking, and trading (CA-ABT) credit program, similar to the federal ABT program currently part of the nonroad diesel regulations
 - Necessary to account for differences in California (CA) vs. United States Environmental Protection Agency (U.S. EPA) standards after California Air Resources Board (CARB) adopts Tier 5, and to prevent previously banked credits from circumventing Tier 5
- CARB staff and Southwest Research Institute (SwRI), together with industry's input, developed a suitable low-load test cycle for certifying off-road diesel engines under representative low-load operating conditions for 56-560 kilowatts (kW)
- Accelerated aging protocol for diesel engines developed by SwRI:
 - Shorten the certification effort for engines equipped with selective catalytic reduction (SCR) and diesel particulate filters (DPF) by up to 90%

Overview: Proposed Certification Amendments

(2 of 2)

- Clarify the criteria for determining that the cleanest engine available has been selected when replacing in-use diesel equipment
- Align with U.S. EPA's IRAF amendments that have been in place since 2014
- Update deterioration factor preconditioning procedures to better align with U.S. EPA and CARB's recently adopted heavy-duty on-road requirements

Averaging, Banking, and Trading



ABT Background (1 of 2)

- ABT is a federal certification provision that allows engine manufacturers the flexibility to comply with emission standards through averaging, banking, or trading of emission credits
- ABT has been in effect since the first federal nonroad diesel engine standards were implemented in 1996 (Tier 1), and applies to Particulate Matter (PM), Oxides of Nitrogen (NO_x), and combined Non-Methane Hydrocarbons and NO_x (NMHC+ NO_x) pollutants
- Under ABT some engine families may be certified to emission levels less stringent than the standard so long as any excess emissions are offset
- California is a participant in the federal ABT program along with the other 49 states (and U.S. territories), and does not require separate emissions accounting

ABT Background (2 of 2)

- There are no limits to the number of ABT credits that can be banked for future use under the federal program
- Banked credits do not expire nor is their value discounted over time
- Generally, credits may only be used within an averaging set
 - Engines \leq 560 kW, or
 - Engines $>$ 560 kW
- Considerable credits have already been banked by some manufacturers
- Credits generated from Tier 1 engines and Tier 2 engines from 37 to 560 kW, cannot be used to certify Tier 4 engine families

ABT Purpose

- Improve cost-effectiveness of the regulations by not requiring every engine model to be upgraded
- Allow manufacturers to conserve resources by overdesigning a portion of their product line so that some existing products may continue to be sold as is
- Provide the opportunity for longer phase-in periods without decreasing emission benefits on a national basis
- Keep nationwide emission levels at or below emission standards on average
- Incentivize the development of cleaner engines than otherwise required, which can later become the basis for more stringent emission standards

Need for a California-Specific Program

- Off-road diesel engine emission standards may no longer be aligned between CARB and U.S. EPA after CARB adopts Tier 5 requirements
- The federal ABT program does not include credits for tailpipe carbon dioxide (CO₂), which may become a regulated pollutant under Tier 5
- Federal credits do not have to be used proportionally by State
- Theoretically, a manufacturer could use its credits generated from all 50 states in just California to circumvent compliance with the Tier 5 requirements

Federal ABT Credit Equation

$$\text{Credit (kilograms)} = (\mathbf{STD} - \mathbf{FEL}) * \mathbf{Volume} * \mathbf{Avg Power} * \mathbf{UL} * \mathbf{10^{-3}}$$

Where:

STD = applicable emission standard, in grams per kilowatt-hour, that applies for engines not participating in the ABT program

FEL = family emission limit for the engine family, in grams per kilowatt-hour (usually the previous Tier standard)

Volume = actual U.S.-directed end-of-year production volumes within the given engine family during the model year

Avg Power = average value of maximum engine power values for the engine configurations within an engine family, calculated on a sales-weighted basis, in kilowatts

UL = useful life for the given engine family, in hours

10⁻³ = grams to kilograms conversion factor

California-Specific ABT Proposal (1 of 3)

- CA-ABT program would balance NO_x, PM, CO₂, N₂O and CH₄ at the State level
- A new California-specific credit bank would be created in 2026 to store credits from early Tier 5 final compliant engine families and zero-emission (ZE) powertrains
- A portion of existing federal credit balances would be transferred into the California-specific bank in 2029
 - California bank equal to the California percentage of federal sales for each manufacturer over the previous five-year period average
- Federally transferred credits generated by Tier 4 engines would be available for use in California to certify Tier 5 final, and Tier 5 interim engines under phase-in Option 3 beginning in 2029
- Credits generated from Tier 5 final engine families and ZE powertrains would also be available for use in California to certify Tier 5 final, and Tier 5 interim engines under phase-in Option 3 beginning in 2029

California-Specific ABT Proposal (2 of 3)

- Tier 5 interim engines cannot generate credits
- Current off-road diesel engine averaging sets would be combined into a single averaging set applicable to any engine family across all power ranges in California
- New FEL cap would be the Tier 4 final standard for each power category
- A credit sunset date of five years would be applicable to all credits to protect against future Tier 5 circumvention from the banking of credits
- Starting with Tier 5 final, manufacturers may certify 5% of their annual production volumes for up to five years as Tier 4 final carryover engines at a credit discount rate of 70%.*

*Applies to engines not subject to the low load cycle (LLC), off-road in-use testing (ORIUT), greenhouse gas (GHG) standards, lengthened useful life/warranty, idle restrictions, or on-board diagnostics / on-board monitoring (OBD/OBMD)

California-Specific ABT Proposal (3 of 3)

- New CA-ABT provisions for tailpipe CO₂, nitrous oxide (N₂O), and methane (CH₄) credits, are being proposed in a one-way trading program*, i.e., CO₂ to N₂O or CH₄, but not vice versa, similar to what was adopted by U.S. EPA for on-highway engines
 - Keeps in check unwarranted credit generation from N₂O and CH₄ capping standards
- Credit multipliers would apply for early Tier 5 final compliance from the 2026 through 2028 model years (MY)

* The proposed one-way off-road tailpipe GHG credit trading program is described in Slide Deck #2 under the CO₂ standards section

Tier 5 CA-ABT Credit Fundamentals

2026

- **CA-ABT Bank Created:** Unique CA-specific credit pool for California's independent ABT program would be created in 2026

2026-2028

- **Early Credits with Multipliers:** Credits could be deposited into the CA-specific credit pool by meeting Tier 5 final requirements early from 2026-2028; multipliers apply

2029

- **ABT Credits Split into Federal and CA Pools:** A portion of existing ABT credits in the federal credit pool would be transferred into the CA-specific credit pool in 2029
- The transfer of credits into the CA-specific credit pool would be a one-time event

Tier 5 CA-ABT Credit Fundamentals

2029

- **CA Portion of Tier 4 Federal Credits:** Only Tier 4 credits would be transferred from the federal credit pool varying by manufacturer, equivalent to each manufacturer's CA percentage of federal sales averaged over the previous five years
- Credits in the CA-specific credit pool could only be used to certify (some) Tier 5 engines

2029-2033

T5 Interim
(years vary by power
and option)

- **Tier 5 Interim Engines:** Tier 5 interim engines could only use CA-specific credits under the phase-in Option 3
- Tier 5 interim engines could not generate emission credits for deposit into the CA-specific credit pool

2031+

T5 Final
(years vary by power
and option)

- **Tier 5 Final Engines:** Tier 5 final engines could both generate into, and use credits from, the CA-specific credit pool
- Credits could be deposited into the CA-specific credit pool by exceeding Tier 5 final requirements anytime within the Tier 5 final timeframe

Tier 5 CA-ABT Credit Fundamentals

Credits not available under Tier 5 CA-ABT

- **Credit Availability:**
 - Credits based on FELs either more stringent than Tier 4 but less stringent than Tier 5 final OR more stringent than Tier 5 interim but less stringent than Tier 5 final would not be available for deposit into the CA-specific credit pool
 - Any credits generated in reference to the Tier 4 standards would not be available for deposit into the CA-specific credit pool, except those generated before 2029 and transferred into the CA-specific pool

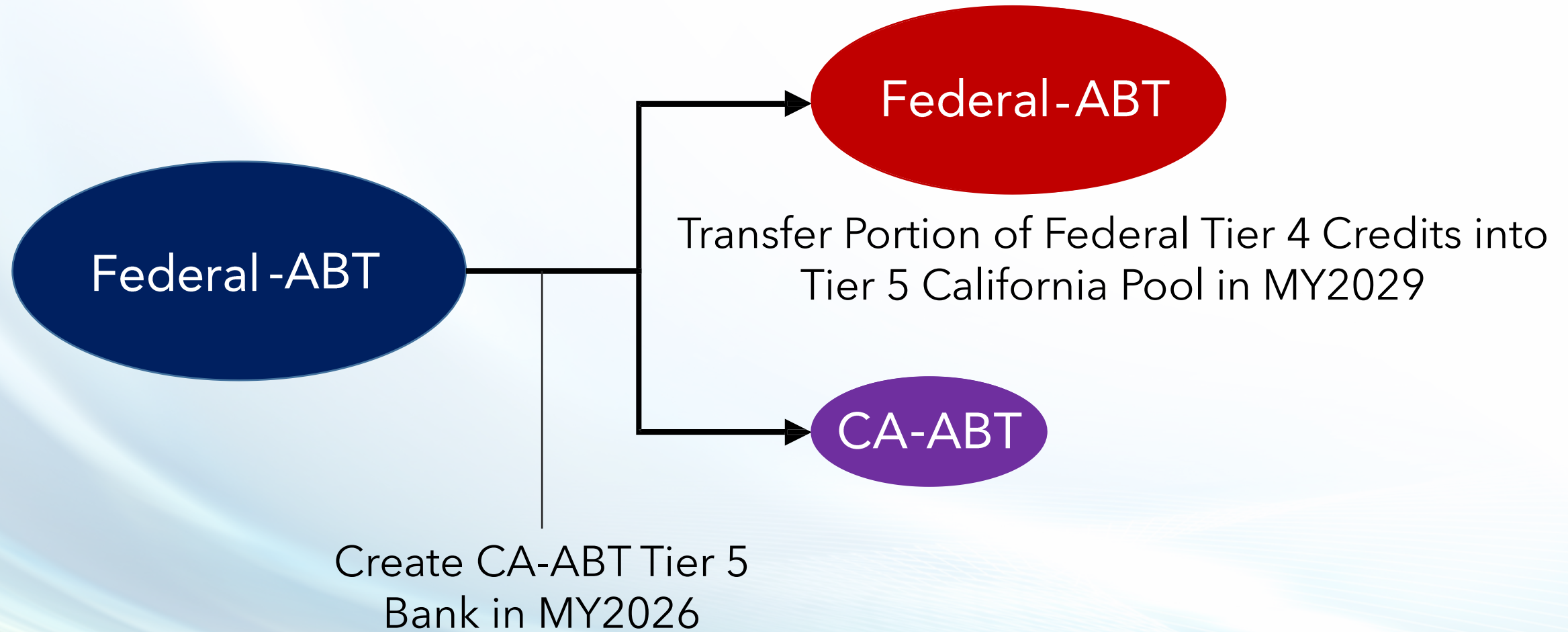
Other Requirements

- **Credit Expiration:** All credits would expire within five years
- **ZE Credits:** Credits could be deposited into the CA-specific credit pool by producing ZE powertrains anytime, but if early, then multipliers apply
- **Carryover:** Limited Tier 4 final engines carryover at 5% / 5 years / 70% credit discount

Incentives for Early Tier 5 Compliance

- NO_x Credit Multipliers
 - 1 year early
 - NO_x credit multiplier = 1.25x
 - 2 years early
 - NO_x credit multiplier = 1.5x
 - 3 years early
 - NO_x credit multiplier = 1.75x
- No Multipliers for PM or CO₂

Tier 5 ABT Split Banks



California ABT Credit Equation

$$\text{Credit (kilograms)} = (\mathbf{MULT}) * (\mathbf{STD} - \mathbf{FEL}) * \mathbf{Volume} * \mathbf{Avg Power} * \mathbf{UL} * \mathbf{10^{-3}}$$

Where:

MULT = Early Tier 5 compliance credit multiplier (only to generate CA NO_x credits):

STD = applicable emission standard, in grams per kilowatt-hour, that applies for engines not participating in the ABT program

FEL = family emission limit for the engine family, in grams per kilowatt-hour

Volume = actual California-directed end-of-year production volumes within the given engine family during the model year

Avg Power = average value of maximum engine power values for the engine configurations within an engine family, calculated on a sales-weighted basis, in kilowatts

UL = useful life for the given engine family, in hours

10⁻³ = grams to kilograms conversion factor

Credit Question:

Between 2026 and start of Tier 5 final, can a manufacturer generate credits by certifying engine families to below the Tier 4 final standards?

- If the FEL of the engine family is less stringent than the Tier 5 final standard, then all credits would continue to be deposited into the federal pool
 - A portion of these credits equal to the manufacturer's California percentage of federal sales would be transferred from the federal pool to the California pool in MY2029
 - The transferred portion of credits could be used to offset certification levels for Tier 5 interim engines in Option 3 or Tier 5 final engines beginning with MY2029
- If the FEL of the engine family is more stringent than the Tier 5 final standard then all credits would be deposited into the California ABT pool
 - All these credits, including multipliers, could be used to offset the certification levels of Tier 5 final engines beginning with MY2029
 - All these credits, including multipliers, could be used to offset the certification levels for Tier 5 interim engines used in Option 3 beginning with MY2029

Proposed Clarification of New Replacement Engine Provisions



Issues and Goals

Issues:

- Current reporting requirements for new replacement engines, per 13 CCR 2423(j)(2), are insufficient to accurately track the number of replacement engines in California or their emissions impact
 - Estimated ~2% of current new engine sales
- Rebuilt engines include:
 - 1) original engines that have been overhauled and reinstalled into the same piece of equipment, and
 - 2) engines sourced from other equipment(s) that have been overhauled and which replace the original engine
- Volume of rebuilt engines produced for California and their emissions impact are unknown

Goals:

- Better recordkeeping and reporting
- Ensure that the cleanest engines are used to repower California off-road equipment
- Understand emissions impact of new replacement and rebuilt engines

Current New Replacement Engine Provisions

13 CCR 2423(j)

Manufacturers must:

- Ascertain that no currently certified engine is available with the appropriate physical or performance characteristics to repower the equipment
 - Replacement engine must meet the cleanest feasible standard, or match the tier of the engine being replaced if no other cleaner engines are available
- Take possession of the engine being replaced or confirm the engine has been destroyed
- Not use the replacement-engine exemption to circumvent the standards
- Clearly label the replacement engine
- Provide, by engine model, the actual number of replacement engines produced for California during the model year, and a description of the physical or performance characteristics of those models that indicate certified replacement engines were not available

Proposed Clarification of New Replacement Engine Reporting Provisions (1 of 3)

Manufacturers must complete and submit a checklist as a condition to sell new replacement engines in California:

- Identify the equipment, including serial number, for which the engine is to be replaced
- Identify all engines, by family, model number, power category, and emissions tier, that you investigated in determining that a cleaner engine was not available (replacement engine must meet the cleanest feasible standards, or match the tier of the engine being replaced if no other cleaner engines are available)
- Identify the specific characteristics that you found *incompatible* with the cleaner engine
- Provide specifications justifying the identified incompatibilities
- Identify the modifications needed to alter the equipment to use the cleaner engines you rejected as incompatible
- Attest in a letter that this information is accurate, and you performed due diligence in selecting the cleanest emissions configuration

Proposed Clarification of New Replacement Engine Reporting Provisions (2 of 3)

Manufacturers must provide by September 30 of the year following the end of the model year:

- A list of the replacement engines, by engine family name, engine model, power category, and tier level, produced for California during the model year, paired with the original engines being replaced described by engine family name, engine model, power category, and tier level
- A completed checklist for each replacement engine produced and sold during the model year
- The total number of both new replacement engines and new certified engines produced and sold for California
- The attestation letter

Proposed Clarification of New Replacement Engine Provisions with Mandatory Reporting (3 of 3)

- New replacement engines may not generate or use emission credits nor be part of any associated credit calculations



Current Records Requirements for Rebuilt Engines

California Exhaust Emission Standards and Test Procedures for New 2011 and Later Tier 4 Off-Road Compression-Ignition Engines (Part I-F), §1068.120(j) and (k)

Rebuilder must:

- Keep records that:
 - Identify the hours of operation at the time of rebuild
 - Identify the work done on the engine or any emission-related control components, including a listing of parts and components that were used
 - Describe any engine parameter adjustments
 - Identify any emission-related codes or signals that were responded to and reset
- Keep records for at least two years after rebuilding an engine
- Provide records to CARB upon request

Proposed Manufacturer Reporting Requirements for Rebuilt Engines (1 of 2)

Manufacturers who rebuild off-road compression-ignition engines must report by September 30 of the year following the end of a model year:

- Actual number of rebuilt original engines and rebuilt replacement engines by engine family name, engine model, power category, and tier level, for California during the model year
- Document any changes to the emissions configuration of the engine
 - Include the engine family name of the engine being rebuilt
 - Include the reference engine family name corresponding to the emissions configuration of the rebuilt engine

Rebuilt original engines either remain installed in a piece of equipment during the rebuilding process or would be reinstalled after the rebuilding process has been completed.

Rebuilt replacement engines may be known as “remanufactured” engines.

Proposed Manufacturer Reporting Requirements for Rebuilt Engines (2 of 2)

- Product number (or other identifier) of the rebuild kit and/or the replacement components
- Serial number of the engine to track how many times it has been rebuilt
- Hours of operation (or mileage) at the time of rebuild
- Work done on the engine or any emission-related control components, including a listing of parts and components that were used
- Any engine parameter adjustments
- Any emission-related codes or signals that were responded to and reset
- Equipment, including serial number, for which each engine is replaced

Rebuilt original engines either remain installed in a piece of equipment during the rebuilding process or would be reinstalled after the rebuilding process has been completed.

Rebuilt replacement engines may be known as “remanufactured” engines.

Diesel Aftertreatment Accelerated Aging Cycle



Off-Road DAAAC Aging Protocol Applicability

- An off-road DAAAC aging protocol option would be available for all off-road power categories with diesel aftertreatment-based emission controls
 - Would include $19 \leq \text{kW} < 56$, as these would require an aftertreatment system
 - Would also apply to > 560 kW (such as large generator sets) as these would require an aftertreatment system provided appropriate fields input data is available
- Manufacturers may begin using off-road DAAAC to certify diesel engines as early as MY2029 so long as the engine is configured such that DAAAC aging is appropriate for the aftertreatment system
- The off-road DAAAC protocol would be the preferred method for accelerated aging of off-road diesel engines
- Manufacturers must continue to test engines for at least 1,500 hours of actual aging on the dynamometer to determine deterioration factors

DAAAC Summary

- DAAAC is not a universal test cycle, rather it is a protocol for determining an appropriate aging cycle for a specific engine family
- An off-road-specific DAAAC protocol is necessary to accurately represent the operation and aging characteristics of off-road diesel engines despite similar heavy-duty on-road design technologies
 - Off-road has a greater variety of operational applications
 - Off-road has wider power ranges than on-road heavy-duty
 - The off-road environment is typically harsher than the on-road environment
 - Rapid load changes, e.g., dozers repeatedly filling, lifting, and dumping buckets
 - Extended operation at full loads

Infrequent Regeneration Adjustment Factor Considerations and Preconditioning



IRAF Background

- IRAFs are used for calculating and applying emission adjustment factors for engines with aftertreatment technology that may have infrequent regeneration events that occur during testing. They are used to adjust testing results to demonstrate compliance with emission standards.
- Currently, CARB requires that the IRAF calculation is performed in accordance with the California Test Procedures Part I - D, Part 1039.525
- The U.S. EPA has enhanced IRAF calculations by amending the requirements of 40 CFR 1039.525 and incorporated section 40 CFR 1065.680 (Adjusted emission levels to account for infrequently regenerating aftertreatment devices)
 - Detailed instructions for calculating F^* , specific insights into the regeneration type and test cycles
 - The IRAF requirements in 1039.525 are required when using accelerated aging to determine deterioration factors

* $F[\text{cycle}]$ = the frequency of the regeneration event during the test segment, expressed in terms of the fraction of equivalent test segments during which active regeneration occurs

Infrequent Regeneration Adjustment Factor Calculation Proposal

- Align with recently adopted federal requirements for IRAF calculations by incorporating portions of 40 CFR 1065.680 into the California test procedures for off-road diesel engines, Part I-E (Part 1065)
- Amend 1039.525 of the California Test Procedures, Part I-D (Part 1039) to incorporate portions of 40 CFR 1065.680 including:
 - IRAF calculation methodology outlined in 1065.680
 - Upward Adjustment Factor (UAF) and Downward Adjustment Factor (DAF) are determined based on the occurrence of active regeneration
 - Formulas utilized to calculate the Emission Factor, UAF, and DAF contain explicit information about the type of test cycles being considered
 - Frequency of regeneration is explained in more detail and determined using a specific equation subject to certain provisions

Engine Preconditioning Proposal

- Staff plans to add section 1065.518 to California test procedures Part I - E (Part 1065) to align with U.S. EPA 40 CFR 1065.518
- Section 1065.530 of California Test Procedure Part I - D (Part 1039) would be amended to incorporate 1065.518 requirements:
 - The engine preconditioning requirements outlined in 1065.518
 - Cold-start transient cycle
 - Hot-start transient cycle
 - Hot-running transient cycle
 - Discrete-mode cycle for steady-state testing
 - Ramped-modal cycle for steady-state testing
- Under the current California Test Procedure 1065.530, sampling systems are required to undergo preconditioning as described in 1065.520(f). This preconditioning is dependent on torque, speed, and flow rate, rather than being associated with a specific test cycle.

Backup Slides

Detailed CA-ABT Question

- Could a manufacturer certify an engine family to an FEL of 0.05 grams per kilowatt-hour (g/kW-hr) NO_x under Tier 4 final and then use the credits generated to continue certifying more of the same engine family under Tier 5?

Answer

- Consider an engine family consisting of a single engine certified to an FEL of 0.05 g/kW-hr NO_x, an average maximum power rating of 200 kW, and a useful life period equal to 8,000 hours:
 - Prior to Tier 5 becoming mandatory, credits are determined based on the Tier 4 final std
 - $(0.40 \text{ g/kW-hr} - 0.05 \text{ g/kW-hr}) \times 1 \text{ unit} \times 200 \text{ kW} \times 8,000 \text{ hours} \times 0.001 \text{ kg/g}$
= (**560 kg credit**)
 - After Tier 5 becomes mandatory, credits are determined based on the Tier 5 final std
 - $(0.04 \text{ g/kW-hr} - 0.05 \text{ g/kW-hr}) \times 1 \text{ unit} \times 200 \text{ kW} \times 8,000 \text{ hours} \times 0.001 \text{ kg/g}$
= (**-16 kg credit deficit**)
- Numbers indicate a manufacturer could offset 35 future engines under Tier 5 final for one identical engine certified a year earlier under Tier 4 final, i.e., $560 \div 16 = 35:1$
- Other factors must be considered to determine the correct application of credits:

Answer cont'd

- Prior to 2029, only the manufacturer's portion of credits equal to its California percentage of federal sales would be available to use on the Tier 5 engine
 - If the manufacturer's California percentage of federal sales is 10%, then only 56 kg of credits would be available to offset the -16 kg deficit, reducing the offset ratio to 3.5:1
 - CA-ABT credits could be subject to 70% discounting to compensate for lacking Tier 5 elements, e.g., LLC, CO₂, In-Use Testing, OBD, etc. This would result in 16.8 kg remaining to offset the -16 kg deficit, meaning that an approximate 1:1 relationship would exist between Tier 4 final credits generated and Tier 5 final credits needed
- After 2029, Tier 4 final credits would not be eligible for use on California Tier 5 engines and would be deposited into the existing federal bank
- All credits deposited into the CA-specific credit pool would expire after five years*

* Although credits may be used as early as 2029 to offset Tier 5 interim Option 3, the five-year clock would not start until the commencement of Tier 5 final standards