California Council on Diesel Education and Technology

CCDET IV

Student Guide

Smoke Testing
Commercial Harbor Craft (CHC)

Student Guide
May 2023

TWI
Transportation Workforce Institute

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Course Overview

This one-day course covers implementing Periodic Smoke Inspection for Commercial Harbor Craft (CHC). It includes the environmental and health impacts of particulate matter, smoke test regulations, requirements, and standards as they apply to CHC, SAE J1667 Snap-Acceleration Test procedures with specific variations for CHC, Opacity Test fail procedures, and an overview of using Method 9 to assess smoke opacity from stationary sources. The course includes both classroom and hands-on components.

This course was created pursuant to the amended CHC Regulation Order California Code of Regulations, Title 17, Section 93118.5, that became effective on December 30, 2022. The California Council on Diesel Education and Technology (CCDET) is a consortium of diesel truck and bus engine manufacturers and dealers, California community colleges, and the California Air Resource Board (CARB). The community college partners include College of Alameda, American River College, Los Angeles Trade-Technical College, Palomar College, San Joaquin Delta College, and Santa Ana College. The Transportation Workforce Institute (TWI) coordinates curriculum development among the CCDET partner colleges.

I. Learning Outcomes and Objectives

Course Learning Outcomes

A. Workers, owners, and managers of businesses using Commercial Harbor Craft operations will be able to maintain their engines in compliance with CARB regulations.

B. Class participants will be aware of specific regulatory requirements for Commercial Harbor Craft and how they differ from other smoke-test procedures.

C. Participants will be able to perform a J1667 Snap Acceleration Procedure modified for Commercial Harbor Craft.

Learning Objectives

Upon completion of the course, participants will be able to:

1. Identify health & environmental effects of air pollution and diesel particulate matter.
2. Identify smoke test regulations, requirements, and standards as they apply to Commercial Harbor Craft.
3. Correctly perform an SAE J1667 Snap-Acceleration Test simulation with the modified procedure for Commercial Harbor Craft.

II. Course Agenda

The following tables provide the agenda for this 4-hour course. There will be a short break approximately every two hours. There is no scheduled meal break because the course meets for only a half-day.

DAY 1	
15 Minutes	**Introduction** • Housekeeping tasks (sign-ins, etc.) • Course overview and objectives • Review of Course Agenda **Implementation Dates and Schedule** **Scope of Opacity Testing for CHC** **Environmental Impacts of Diesel Particulate Matter** • Why these programs are needed • Detrimental effects of different pollutants • Specific health effect of diesel particulate matter **Smoke Meters** **Special Consideration for CHC** **Snap-Acceleration Test Procedures** **Method 9 Overview**
15 Minutes	**Break**
90 Minutes	**Hands-on Snap-Acceleration Test Procedures**
30 Minutes	**Assessment**

III. Course Information

COURSE NAME:	CCDET IV: Smoke Testing Commercial Harbor Craft (CHC)
APPROVED:	TBD
CLASS TIME:	4-6 Hours
PREREQUISITES:	None
MAXIMUM CLASS SIZE:	20 Participants
TARGET AUDIENCE:	Service technicians, CARB-regulated stakeholders, CHC owner/operators, fleet operations managers, and any others responsible for CARB CHC regulatory compliance
CERTIFICATE(S):	CCDET Course Completion Certificate

TRAINING AIDS AND EQUIPMENT:

- ☑ Smart Board and/or Projector
- ☑ Computer
- ☑ Whiteboard
- ☑ Personal safety equipment
- ☑ Maintenance reference documentation
- ☑ Vehicle / Engine Keys (Crew, operating, and maintenance keys)
- ☑ Set of maintenance tools
- ☑ PowerPoint Presentation
- ☑ Opacity Meter

HANDOUTS:

- ☑ Exercise Handouts
- ☑ Participant Handouts

PARTICIPANT EVALUATION METHODS:

- Written Final Assessment 100%

HANDOUTS

SAE J1667 Snap-Acceleration Procedure Summary – Harbor Craft

Vehicle Preparation & Safety Check	
Air Conditioning	Off
Anything altering normal acceleration	Deactivated
Throttle / Governor	Functioning normally
Exhaust Leaks	Fixed / None
Cautions:	
• Blue Smoke	Unburned hydrocarbons (oil)
• White Smoke	Water vapor (possible coolant leak)
• Black Smoke	Rich mixture / Unburned fuel

Ambient Air Test Conditions	
Altitude	1,500 ft above sea level
Air Temperature	Below 38°F or above 86°F
Wind	Avoid or Use wind-sheltered area
Dry Air Density	0.0567 to 0.0771 lbm/ft3
Humidity	Avoid fog, rain, & snow

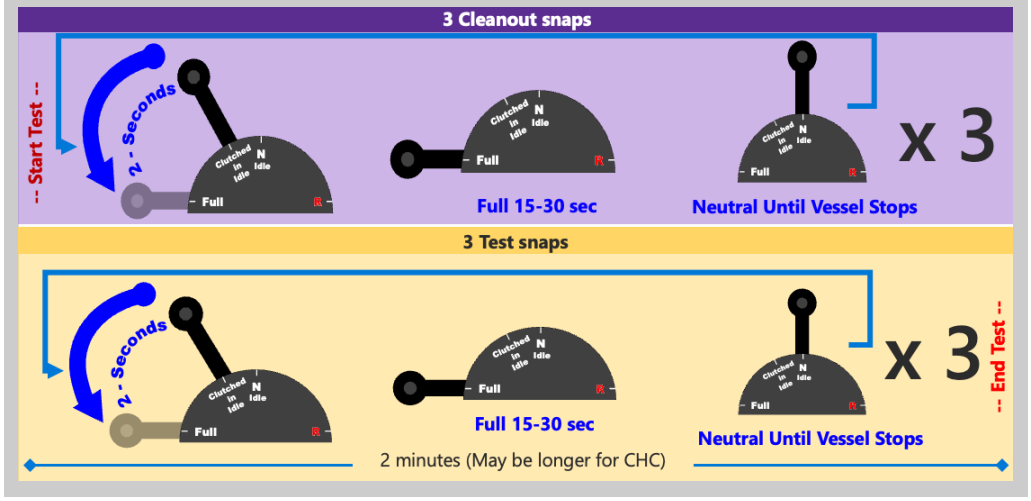
Smoke Meter Calibration	
Warm-up	Warm & stabilize per manual
Zero	No blockage of light beam & Adjust to 0.0% ± 1.0% Opacity
Full Scale	Completely block out light & Adjust to 100% ± 1.0% Opacity
Span (if required; K readout meters)	Use known neutral density filter & adjust to ±0.10 m^{-1}

Test Validation Criteria	
Zero Shift	± 2.0% Opacity or ±0.10 m^{-1} smoke density (K)
Range of Test Snaps	5% Opacity difference max. or 0.50 m-1 (K) max.

Smoke Meter Installation	
If Results in Units of Opacity	Get engine power rating from Emissions Control Label (ECL) or manufacturer literature
Full Flow End-of-Line Meters	
• Light Beam Axis	Perpendicular to exhaust flow
• Light Beam Distance	As close as possible 2.76 in maximum
Sampling Meters	
• Insert	Upstream facing exhaust flow
• Distance from pipe wall	0.197 in (5 mm) Minimum
Tachometer	Useful. Calibrate to mfr. specs.

SAE J1667 Procedure for Commercial Harbor Craft	
A	**Visual Inspection**
B	**Test Procedure**
1	Transit vessel to a safe location in open waters. Stop vessel, attach smoke meter.
2	Clutch-in with engines at idle
3	Transition controls from clutched-in idle to full throttle within 2 seconds
4	Record opacity measurement for 15 seconds or until engine reaches full power
5	Throttle to neutral idle until vessel comes to a full stop. Repeat 6 times (3 cleanout + 3 test snaps)
6	Final opacity measurement is the average of the three test snaps (last three)
C	**Record Keeping / Repair / Retest**

Harbor Craft Snap-Idle Throttle Illustration



Commercial Harbor Craft Summary of the Regulation

Opacity Standards	DPF	Non-DPF
	5%	40%

Vessels Subject to Regulation	• Diesel-fueled harbor craft operated in Regulated California Waters (RCW), includes tugboats, towboats, excursion vessels, ferries, etc. • Biennial Testing (every other year) • Auxiliary engines subject to same standard but no biennial testing requirement
Exemptions	• Continuous expeditious navigation through RCW without calling to port or entering internal waters • Oceangoing vessels except tug & tow boats • Coast Guard, military tactical, dedicated Emergency Vessels, and temporary Rescue/Recovery Vessels
Testing	**Placement** • At pipe or stack for dry exhaust • Bung or sampling port for wet exhaust, after DPF but before water introduced **Testing** • Vessel underway in open waters • Clutch-in at idle and transition to full load within 2 seconds • Measure opacity for 15 seconds or until full power, whichever is longer • *Visual Method 9 may be used for at port auxiliary engines*
Interpreting Results	• Average of the three test snaps • May take longer than 2-minute limit specified for J1667
Fail Procedures	**Main Engine Fail:** • 30 calendar days to repair and retest • Otherwise, must be taken out of service • Retain records of all failed and passed tests. Records are retained for the life of the engine **Auxiliary Engine Fail:** • 30 calendar days to repair and notify carb

Record Keeping

Vessel / Engine
- ✓ Opacity standard for engine
- ✓ Unique Identifier (UVI)
- ✓ Engine Year, Make, Model
- ✓ Serial Number
- ✓ Engine Family (if applicable)

Meter
- ✓ Brand & Model
- ✓ Meter & chart recorder last calibration date

Meter Operator
- ✓ Name, phone, & email
- ✓ If a test contractor: Name & address of contractor company

Opacity Test
- ✓ Test Date
- ✓ Hours meter reading
- ✓ Test Results (3 readings & avg)
  - Test printout or electronic raw test data
- ✓ Pass or Fail

Failure & Retest Records
- ✓ Out-of-service date & hr. meter
- ✓ Post Repair Test Date & hr. meter
- ✓ Post repair test results (as above)
- ✓ Post repair pass or fail
- ✓ Back-in-service date & hr. meter reading

Repair Records
- ✓ Mechanic(s) names
- ✓ Date of repair & hr. meter reading at start of repair
- ✓ Statement Identifying:
  - ✓ Failed components,
  - ✓ Reason for failure
  - ✓ Nature of repair
  - ✓ Itemized parts list

POWERPOINT SLIDES

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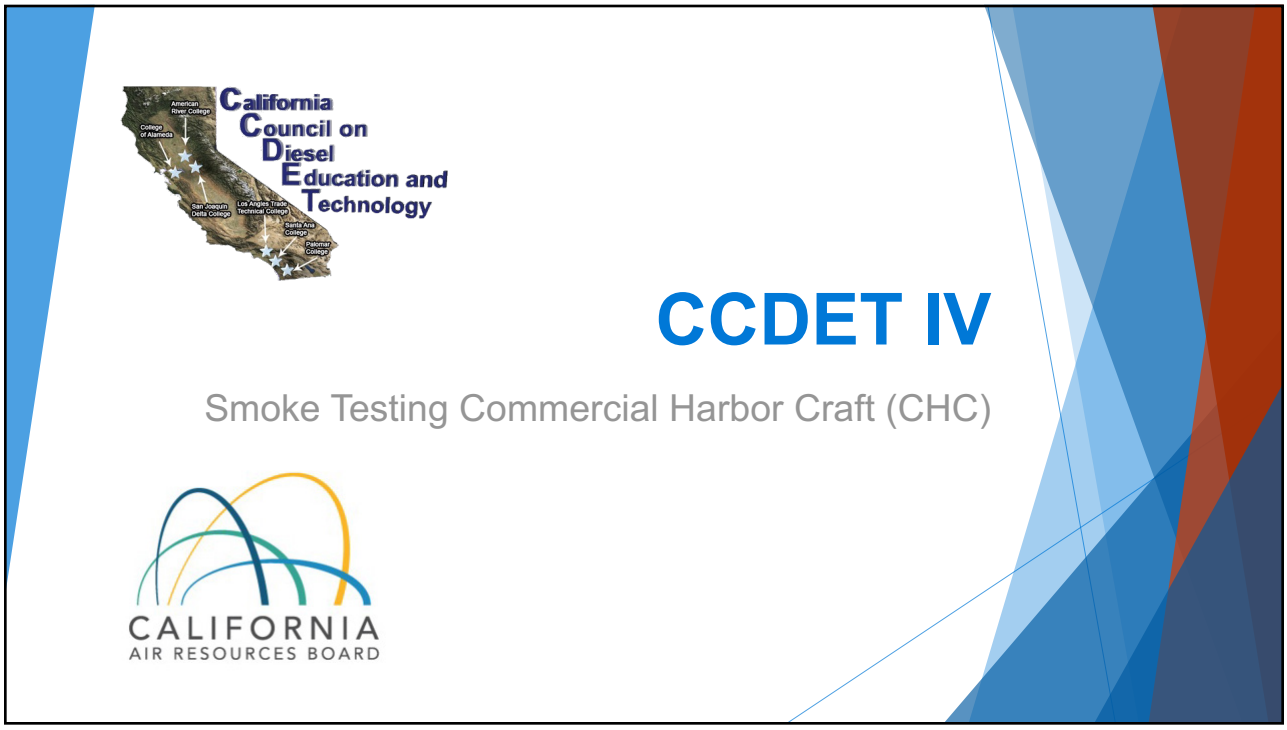

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Implementation Date and Testing Schedule

- Vessel owner or operator must test **by March 31, 2024**
- Test biennially (**every two years**)
- Must **test and report to CARB** by March 31 in **even numbered years** (2024, 2026, 2028, etc.)
- Exempt for 4 years after model year of engine (2020 & newer)

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Scope of the Opacity Testing for CHC?

Subsection (k):

- Commercial Harbor Craft in **CA Regulated Waters** tested **every two years**
- **All main propulsion and auxiliary engines**, regardless of model year, tier level, or compliance date
- **Auxiliary engines** must be compliant but are **not subject to biennial testing**

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Scope of the Opacity Testing for CHC?

Subsection (k):

- **CARB** may perform confirmatory **field testing at any time** or if a public complaint of excessive smoke is received.

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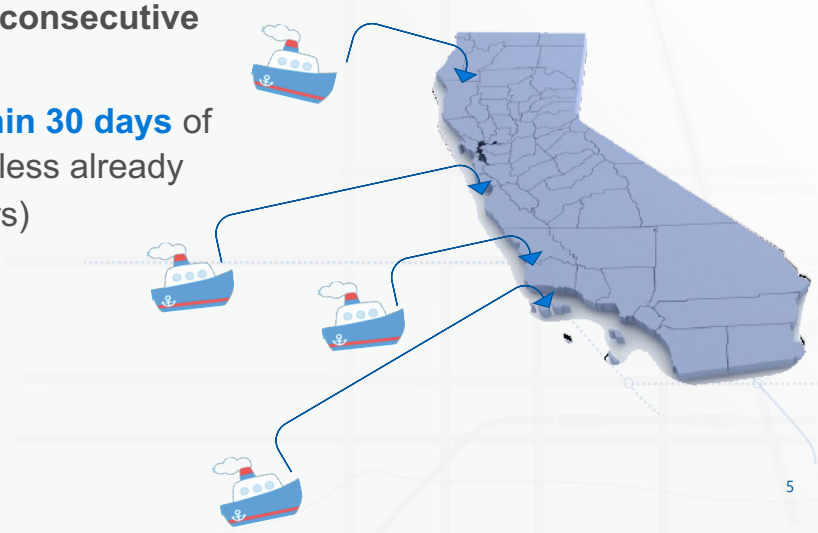
New, from Dry Dock, or Outside California

Will be in RCW for 30 consecutive days:

- **Test and Report within 30 days** of operating in RCW (unless already tested in last two years)



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Environmental & Health Impacts of Diesel Particulate Matter

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Why This Program Is Needed

California Commercial Harbor Craft Emissions (Tons per Day)

	TOG	ROG	CO	NOX	SOX	PM	PM10	PM2.5	NH3
Commercial Harbor Craft	1.74	1.47	5.56	21.01	0.41	0.78	0.78	0.74	-

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Source: https://ww2.arb.ca.gov/applications/statewide-emissions
2017 Estimated Annual Average Emissions, Statewide

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Why these programs are needed

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Health and Environmental Impacts

Constituent	Detrimental Effect
Diesel Particulate Matter (PM)	(PM10/PM2.5) Carcinogenic/Mutagenic Respiratory Disease
HC & NOx (Smog Precursors)	Ozone (smog) Respiratory Disease Crop Losses
NOx & SOx	Acid Deposition Visibility Degradation
Toxic Air Contaminants	Cancer & Other Ill Effects

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Particle Pollution

Air pollution remains a major danger to the health of both children and adults

Contributes to:

- Premature Death
- Developmental harm
- Reproductive harm
- Asthma attack
- Lung Cancer

- Wheezing and coughing
- Shortness of breath
- Cardiovascular harm
- Susceptibility to infections
- Lung tissue redness, & swelling

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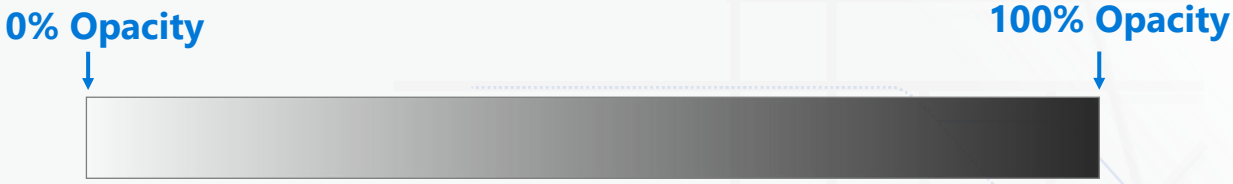
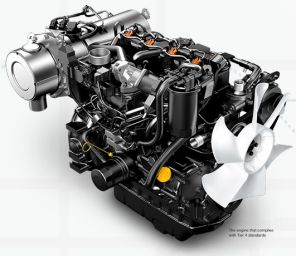
Measuring Emissions

- **Opacity meters** measure pollution by how light travels through exhaust smoke. More transparent (less opaque) means less polluting. More ***opaque*** means more polluting.



Opacity Standards for Commercia Harbor Craft

Opacity Standards	DPF	Non-DPF
	5%	40%



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Smoke Meters

Smoke-testing Diesel Vehicles

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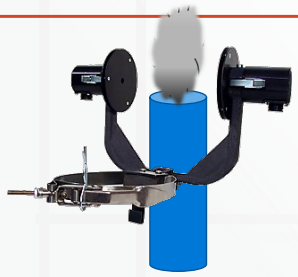
Full Flow v Partial Flow

Full Flow Meters:

- 100% of the exhaust flows through the sensor
- Attachment / placement is critical
- Affected by weather conditions



Partial Flow Meters:

- Senses partial exhaust from pipe or outlet
- Placement not critical (anywhere in the pipe)
- Weather has limited effect

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Before: Know Your Meter

- Smoke Meter must be SAE J1667 compliant
- Meter may adjust readings based on conditions or may not
- Choose your meter depending on, cost, test location, and ambient conditions encountered
- Follow **Owners Manual** regarding installing, cleaning, & calibrating
- Readings are in **% of opacity**

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Before: Test Conditions

All Meter Types:

- Altitude above 1500 feet reading correction
- **Avoid** air **temperature above 86° F or below 36° F**
- **Dry air density** may affect the exhaust smoke opacity

Full Flow Meters

- **Avoid humidity:** No visible fog, rain, or snow in the area where the smoke plume is measured
- **Avoid** excessively **windy conditions**
- **These restriction might make Full Flow meters impractical for Harbor Craft Testing**

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Special Considerations for Commercial Harbor Craft

Smoke-testing CHC

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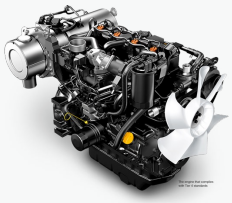
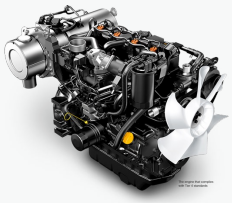
Harbor Craft May Have Multiple Engines

Propulsion Engines





Auxiliary Engines

- Provide power for other uses than propulsion

Swing Engines

- Not subject to section (k) unless installed on vessel

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Testing Schedule (Biennial)

Engine Type	Testing and Reporting Schedule
Propulsion	• Test and Report by March 31, 2024 • Every 2 Years in even numbered years (2024, 2026, 2028, etc.) • Test within the 2-year period; Report by March 31 in report year • Exempt until 4 years after model year of engine
Auxiliary Engines	• Must meet opacity standards but exempt from periodic testing
Swing Engines	• Exempt from section (k) if stored dockside • Subject to rules above if installed in vessel
From Outside CA	• If will be in RCW more than 30 consecutive days, opacity test must be performed and reported to CARB within 30 days* *Unless still exempt or tested & passed within past 2 years
Newly In-service (swing, newly acquired, out of dry dock, etc.)	

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Wet Exhaust v. Dry Exhaust

Wet Exhaust:

- **Seawater** injected into the exhaust flow to cool it down

Dry Exhaust:

- No seawater injected. Similar to exhaust from on-road vehicles

Wet Exhaust & Smoke Meters:

- None of the portable smoke meters manufacturers make a unit capable of sampling wet exhaust

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Meter Head / Probe Placement

	DPF?	Can Sample at Pipe or Stack?	Can Sample at Port or Bung?	Port or Bung Placement
Dry	Yes	Yes	Yes	After DPF
	No	Yes	Yes	After DPF
Wet	Yes	No	Yes	After DPF; Before water injected
	No	No	Yes	Before water injected

- Each engine is tested independently
- If testing at stack, be sure auxiliary engines are not funneling into the same stack

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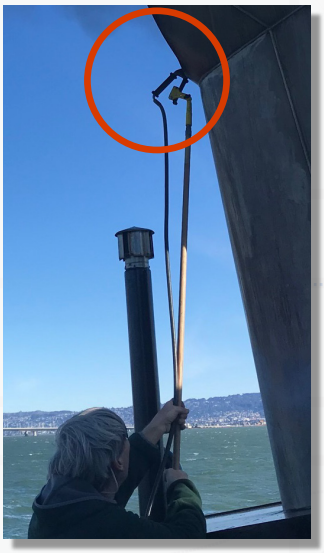
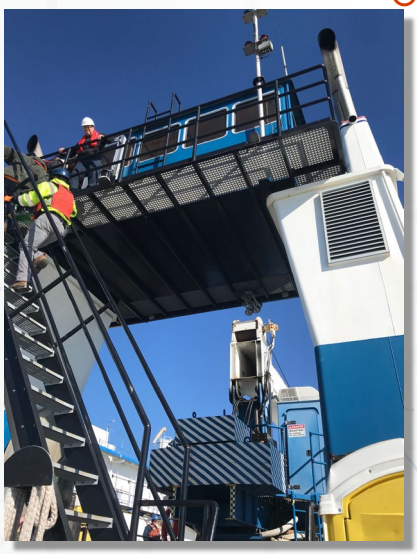
Stack Location - Examples





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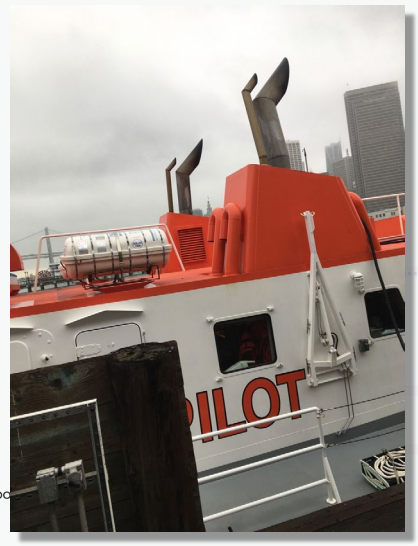
Stack Location - Examples



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Testing Location (Wet Exhaust): Port or Bung

Possible Configuration for Partial Flow Smoke Meter

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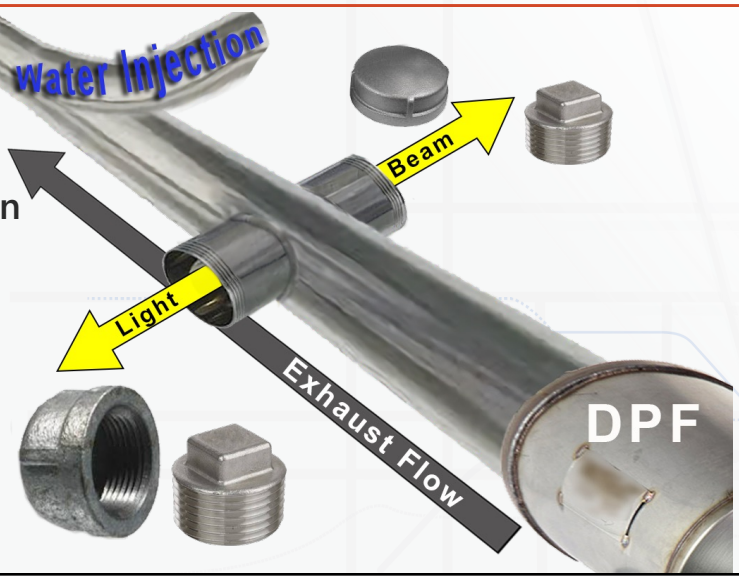
Testing Location (Wet Exhaust): Port or Bung

Possible Configuration for Full Flow Smoke Meter



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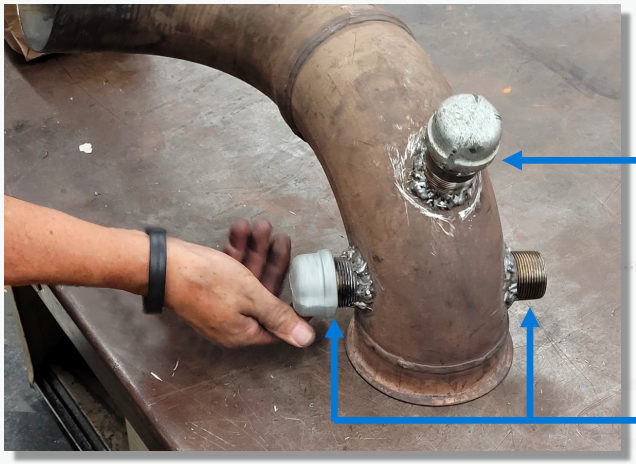
Exhaust Pipe Fitted with Both Types of Port



Single Port for Partial Flow Meter

Dual Ports for Full Flow Meter

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Tester Should Be Able to Observe the Pilot

Special considerations for Harbor Craft:

- The pilot or Captain will work the throttle
- Tester **must observe the pilot** to ensure the **shift from idle to full happens within 2 seconds**
  - Throttling up slower than 2 seconds might falsely lower the opacity reading
  - This might require a **second tester** a **camera system,** or a **meter set to continuous or rolling mode**

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SAE J1667
Snap-Acceleration Procedures

Smoke-testing Diesel Vehicles

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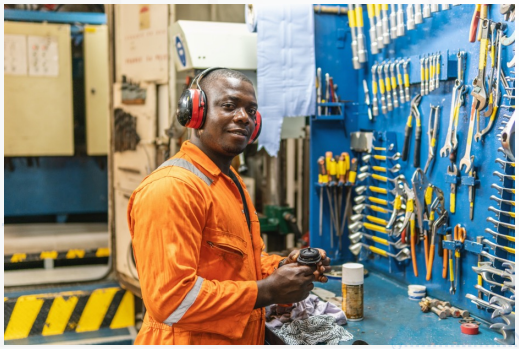
Who May Perform CHC Snap-Acceleration Tests?

Tester Must:

- Complete CCDET training & obtain certification on the specified test procedure
- CARB's Executive Officer may approve or offer alternative training courses that satisfy this requirement



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Pre-test Visual Inspection

Smoke-testing CHC

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Before: Pre-test Inspection

- Check for exhaust leaks and exhaust smoke color
- Look for evidence of tampering
- Verify proper governor speed limiting and engine soundness
- If the visual inspection fails, the smoke test fails

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Performing the Test

Smoke-testing CHC

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SAE J1667 Opacity Test

- Adopted by SAE in February 1996

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Preventive Maintenance for
Heavy Duty Trucks

Snap Idle Test

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CHC Snap Acceleration Test Procedure

Step	Action
1	Transit vessel to a safe location in open waters.
2	Stop vessel, clutch-in with engines at idle.
3	Transition controls from clutched-in idle to full throttle within **2 seconds.**
4	Record opacity measurement for 15 seconds or until engines reach full power (up to 30 seconds), whichever is longer.
5	Transition the throttle to neutral. Wait until vessel reaches dead stop.
6	Repeat test procedure five more times (Steps 2 – 5).
7	Final opacity measurement will be the average of the 0.5-second maximum of the last three accelerations.

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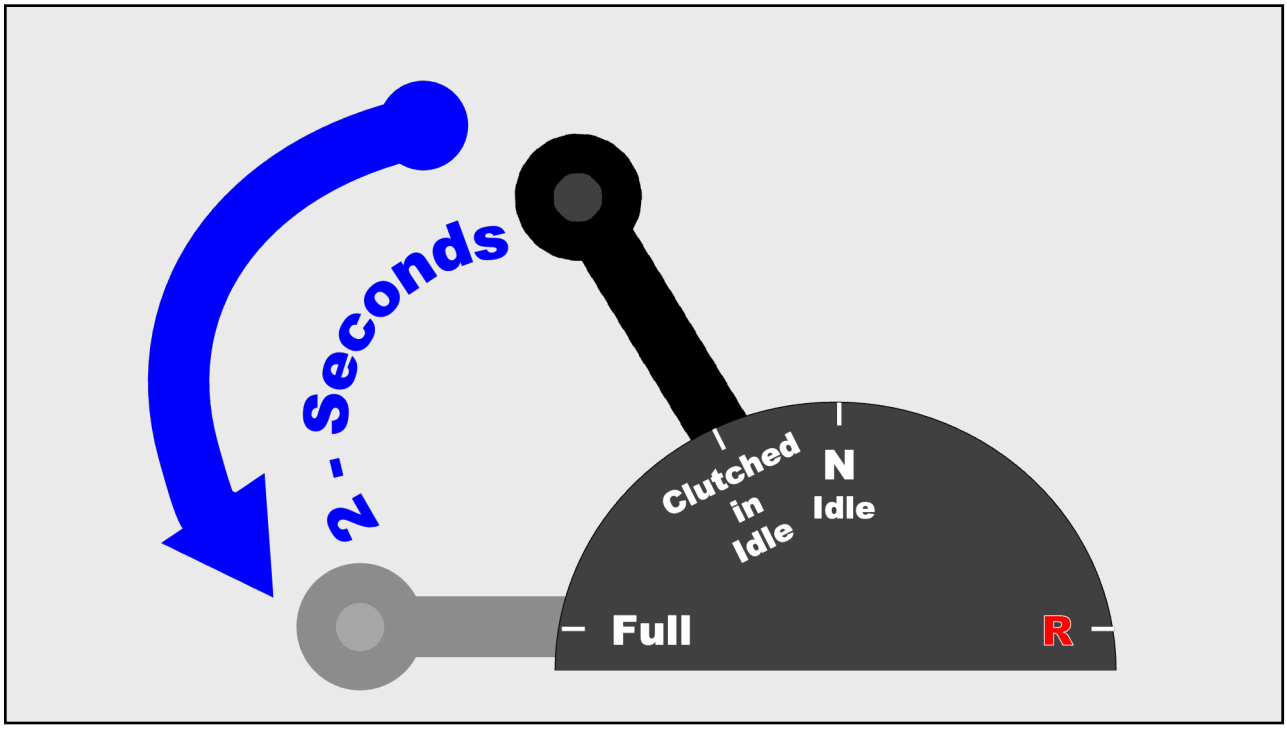

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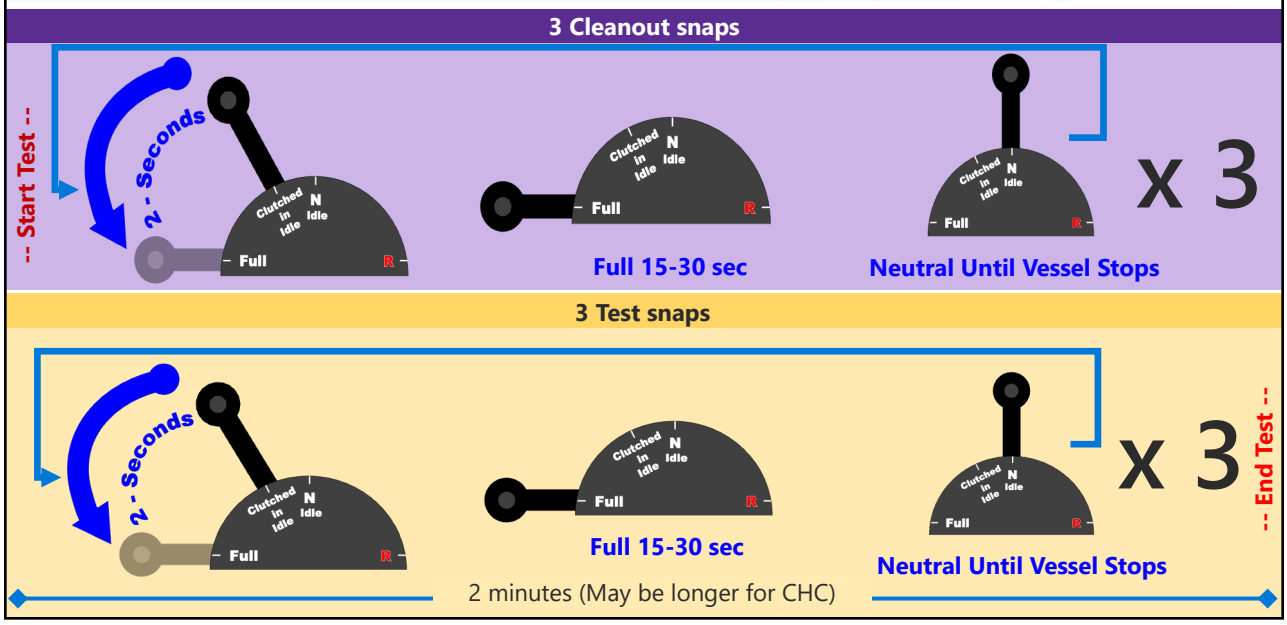
Snap-Acceleration Test for CHC (Repeat for each engine)



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Performing the Test

1. Meter calibrates (Zero: Unobstructed; Full-scale: Fully Obstructed)
2. Perform the Snap:
   a. Pilot engages throttle and moves from **idle, to clutched-in idle. Then move to full within 2 seconds**
   b. When engine reaches max RPM, hold throttle in the **full position for 15 seconds or until the engine reaches max rpm**, whichever is longer (may be up to 30 seconds)
   c. Return to idle
3. Repeat six times (3 cleanout/purge snaps; 3 test snaps)
4. Meter calibrates again. Ensures that there is less than 2% shift from initial calibration

Note: At the beginning of each snap, the tester indicates a new snap in the test meter according the the Owners Manual the opacity meter being used.

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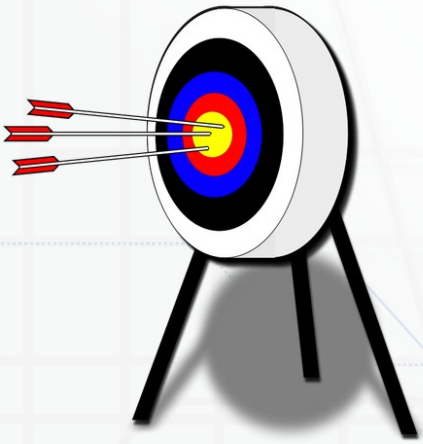
Advice on Being a Good Snap-Acceleration Tester

Stay consistent!:

- The **snaps** should be of **similar lengths**
- The **idle times** should be **similar**
- **Pick a duration** for the snap within the acceptable range, and **try for the same number every time**



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Advice on being a good Snap-Acceleration Tester

Special considerations for Harbor Craft:

- The pilot or Captain will work the throttle
- Tester **must observe the pilot** to ensure the **shift from idle to full happens within 2 seconds**
  - Throttling up slower than 2 seconds might falsely lower the opacity reading
  - This might require a **second tester** or a **camera system**

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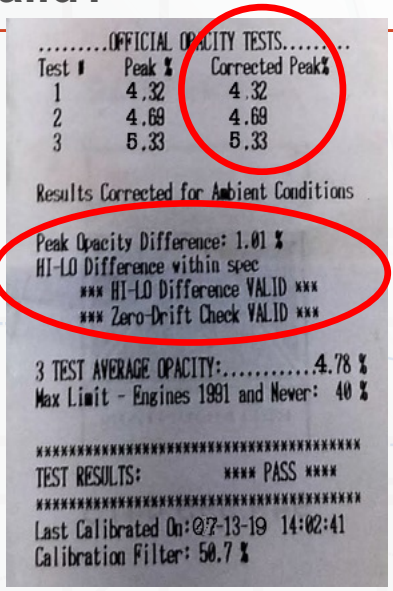
After: Are the Test Results Valid?

Test Validity Check:

- Post-test smoke meter zero shift check - Not to exceed 2% opacity
- The differences between test snaps must not exceed 5% opacity



After: Are the Test Results Valid?

Conditions that will invalidate or cause a failed opacity test:

- Engine not at **operating temperature**
- Improper or **inconsistent** application of the **throttle**
- **Insufficient time** allowed for vessel to come to a **dead stop** between snaps
- Improper **smoke meter installation** on the tail pipe or stack
- **Post-zero shift check** exceeds 2% opacity
  - Possible cause, soot accumulation on the lens/optics of the smoke meter head
- **Intermittent engine emissions control subsystem faults**
  - Failure if the snaps are being applied using consistent methods and one of the snaps has a high measurement that exceeds 40% opacity

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Sample Results

VEHICLE SNAP-ACCELERATION TEST REPORT

Vehicle Exhaust Diameter: 4.0 in
Vehicle Rated HP is in Range: 101-200
"STD" Exh. Diam. for Rated HP: 3.0 in

PROCONDITIONING - FINAL 3 PURGES

Purge	Opacity	"STD" Opacity
1	6.5%	4.9%
2	5.2%	3.9%
3	4.1%	3.1%

PEAK TEST READING AND RESULTS

Test	Opacity	"STD" Opacity
1	6.5%	4.9%
2	5.6%	4.2%
3	7.6%	3.1%
AVERAGE:	6.6%	5.0%
RANGE:	2.0%	1.6%

AMBIENT CONDITIONS CORRECTIONS
Air corrections not used for this test.

	STD	ACTUAL	STD MET?
Number of Purges	3 Min.	4	YES
Number of Tests	3	3	YES
Number of Tests AVGED	3	3	YES
Range of Tests AVGED	5%	1.6%	YES
Peak Average	5%	6.6%	NO
Post-Test Zero Shift	2%	2.5%	NO

FINAL TEST RESULTS: FAIL

VEHICLE SNAP-ACCELERATION TEST REPORT

Vehicle Exhaust Diameter: 5.0 in

PROCONDITIONING - FINAL 3 PURGES

Purge	Actual Opacity
1	6.2%
2	3.7%
3	3.5%

PEAK TEST READING AND RESULTS

Test	Actual Opacity
1	3.4%
2	3.3%
3	3.3%
AVERAGE:	3.3%
RANGE:	0.1%

AMBIENT CONDITIONS CORRECTIONS
Air corrections not used for this test.

	STD	ACTUAL	STD MET?
Number of Purges	3 Min.	4	YES
Number of Tests	3	3	YES
Number of Tests AVGED	3	3	YES
Range of Tests AVGED	5%	0.1%	YES
Peak Average	40%	3.3%	YES
Post-Test Zero Shift	2%	0.0%	YES

FINAL TEST RESULTS: PASS

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Questions, Comments, Clarifications?

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CCDET IV: Smoke Testing Commercial Harbor Craft (CHC)

Snap-Acceleration Fail Procedures

Opacity-testing Commercial Harbor Craft

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Opacity Limit Exceeded

- Repair engine or DPF **within 30 calendar days** or **remove from service**
- Must pass opacity test to return to service
- **Maintain Repair Records of Opacity Testing and Emission Control Repair** specified in (m)(18)
- Same rules for **Auxiliary Engines**
- Must be repaired & retested, and report to CARB

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CCDET IV: Smoke Testing Commercial Harbor Craft (CHC)

Record Keeping

Required CHC Opacity Test and Failure Records

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Repair Record Keeping (Opacity Test)

Vessel / Engine

- ✓ Opacity standard for engine
- ✓ Unique Vessel Identifier (UVI)
- ✓ Engine Year, Make, Model
- ✓ Serial Number
- ✓ Engine Family (if applicable)

Meter

- ✓ Brand & Model
- ✓ Meter & chart recorder last calibration date

Meter Operator

- ✓ Name, phone, & email
- ✓ If a test contractor: Name & address of contractor company

Opacity Test

- ✓ Test Date
- ✓ Hours meter reading
- ✓ Test Results (3 readings & avg)
  - Test printout or electronic raw test data
- ✓ Pass or Fail

Failure & Retest Records

- ✓ Out-of-service date & hr. meter
- ✓ Post Repair Test Date & hr. meter
- ✓ Post repair test results (as above)
- ✓ Post repair pass or fail
- ✓ Back-in-service date & hr. meter reading

Repair Records

- ✓ Mechanic(s) names
- ✓ Date of repair & hr. meter reading at start of repair
- ✓ Statement Identifying:
  - ✓ Failed components,
  - ✓ Reason for failure
  - ✓ Nature of repair
  - ✓ Itemized parts list

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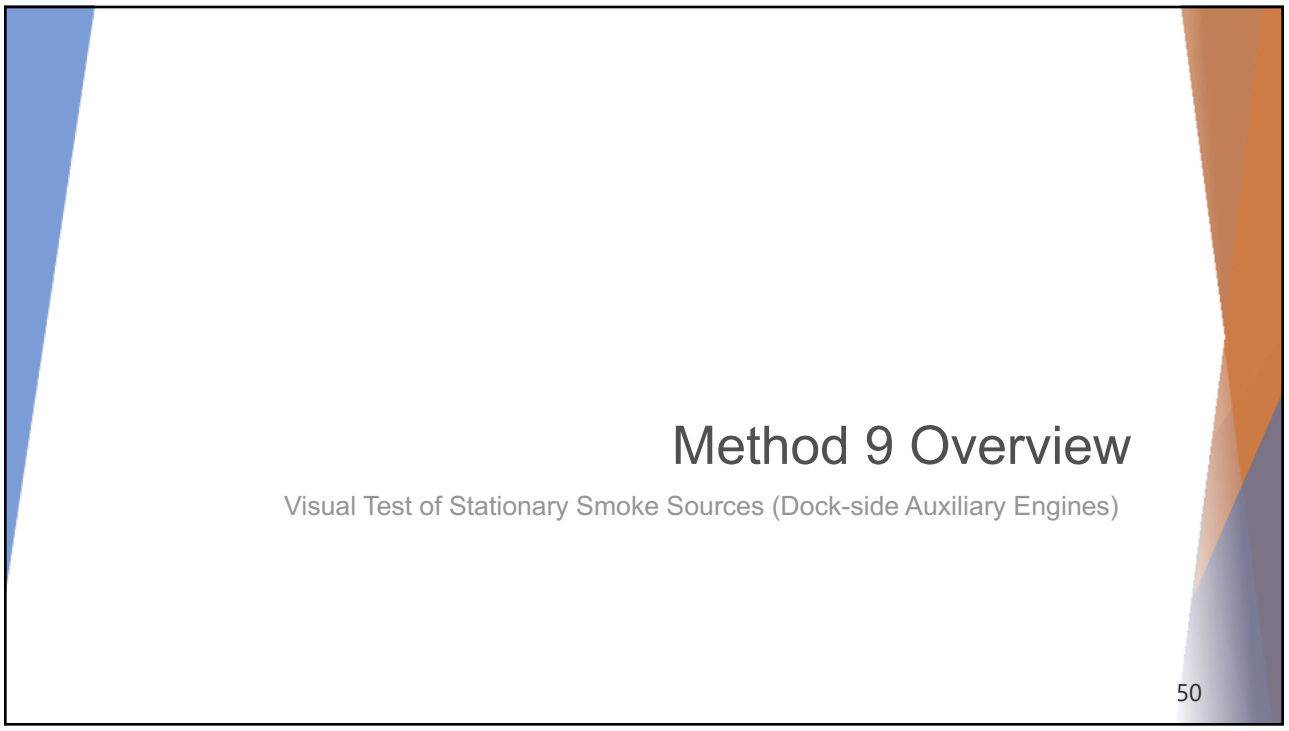

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Method 9 Overview Resources

CARB Resources:

- CARB Visible Emissions Evaluation (VEE) Training
- CARB VEE Training FAQ

Method 9 Resources on the Web:

- https://landairwater.me/2020/10/21/smoke-school-prepares-air-quality-inspectors-to-read-visible-emissions/
- https://www.youtube.com/watch?v=LmakFjwrVIE
- https://compliance-assurance.com/certprocess.php

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Assessment

Written Test

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Hands-On

Practical Exercises with an Opacity Meter

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