

WHEN YOU NEED TO BE SURE



CyFlex® Federal Smoke Cycle User Guide

Version 5

May 25, 2022

Developed by SGS North America, Inc.

Version History

| Version | Date | Revision Description |
|---------|-----------|---|
| 1 | 1/25/2016 | Initial publication |
| 2 | 8/23/2018 | Format to SGS brand |
| 3 | 4/1/2020 | Retrofit to new template |
| 4 | 9/16/2021 | Added hyperlinked cross-references to cyflex.com documentation for <code>svar</code> , <code>nt</code> , <code>floger</code> , and <i>Fast Data Logger Application User Guide</i> . Removed <code>fedSmokeRep</code> usage content from <i>Section 6 Analysis and Reporting</i> on page 28 and replaced with hyperlinked cross-reference to cyflex.com usage help. |
| 5 | 5/25/2022 | Updated all hypertext linked cross-references to cyflex.com usage help descriptions |

Document Conventions

This document uses the following typographic and syntax conventions.

- Commands, command options, file names or any user-entered input appear in Courier type. Variables appear in Courier italic type.
Example: Select the `cmdapp-relVersion-buildVersion.zip` file....
- User interface elements, such as field names, button names, menus, menu commands, and items in clickable dropdown lists, appear in Arial bold type.
Example: **Type**: Click **Select Type** to display drop-down menu options.
- Cross-references are designated in Arial italics.
Example: Refer to *Figure 1*...
- Click intra-document cross-references and page references to display the stated destination.
Example: Refer to *Section 1 Overview* on page 1.
The clickable cross-references in the preceding example are *1, Overview*, and on page 1.

CyFlex Documentation

CyFlex documentation is available at <https://cyflex.com/>. View **Help & Docs** topics or use the **Search** facility to find topics of interest.

Table of Contents

| | | |
|----------|--|-----------|
| 1 | OVERVIEW | 1 |
| 2 | PERFORMING A FEDERAL SMOKE TEST | 2 |
| 2.1 | SAMPLE OUTPUT REPORTS | 3 |
| 2.1.1 | Federal Smoke Cycle Report | 1 |
| 2.1.2 | Federal Smoke Development Report | 3 |
| 2.1.3 | Federal Smoke Test Summary Report | 5 |
| 3 | GENERAL PURPOSE TEST CYCLE | 7 |
| 3.1 | GENERAL PURPOSE TEST SCHEDULER CYCLE SPECIFICATION | 9 |
| 4 | TRANSIENT CONTROL TUNING | 22 |
| 4.1 | TUNABLE VARIABLES | 22 |
| 5 | DATA LOGGING | 24 |
| 5.1 | LOGGER SPECIFICATION | 24 |
| 5.2 | DATA LOGGER OUTPUT FILE | 26 |
| 6 | ANALYSIS AND REPORTING | 28 |
| | APPENDIX A. GENERAL USAGE VARIABLE SPECIFICATIONS | 29 |

LIST OF TABLES

| | |
|---|----|
| TABLE 1: GENERAL PURPOSE TEST CYCLE SECTIONS..... | 7 |
| TABLE 2: GENERAL PURPOSE TEST MODES..... | 7 |
| TABLE 3: TUNABLE VARIABLES..... | 22 |

1 Overview

The Federal Smoke Cycle is applied to engines to measure, analyze, and report the smoke produced by an engine during a specified transient cycle. This document identifies how to perform a federal smoke cycle using CyFlex including:

- Test cycle control
- Control tuning
- Data acquisition process
- Data analysis and reporting
- Data management

The purpose of a federal smoke cycle is to apply a specified set of operating conditions to an engine, and to measure and analyze the levels of smoke produced as a result. The test uses the following CyFlex features:

- `gp_test` to manage the data acquisition and control processes
- `flogger` to acquire data
- `ctrl_task` to control the engine
- General usage labels to manage test parameters
- Engine specifications to specify engine operating parameters and rating information
- Federal smoke report to analyze acquired data and generate reports

2 Performing a Federal Smoke Test

1. Ensure specifications are in place:
 - General usage variables: `gen_labels_nnn`, refer to *Appendix A. General Usage Variable Specifications* on page 29
 - Control: `ctrl_specs.nnn`, refer to *Section 4 Transient Control Tuning* on page 22.
 - Data logger: `logr_spec.fsr`, refer to *Section 5.1 Logger Specification* on page 24
 - General purpose test: `gp_fed_smoke`, refer to *Section 3 General Purpose Test Cycle* on page 7.
 - Smoke report specs: `smkRep_specs.nnn`, refer to *Section 6 Analysis and Reporting* on page 28 and *Section 2.1 Sample Output Reports* on page 3.
2. Ensure reasonable dyno-speed control gains have been established for rated speed and full load.
3. Enter the following to set the test number variable to the desired value - usually incremented from the previous value:

```
svar smk_test <starting test_number>
```

Refer to cyflex.com usage help for [svar](#) for related information.
4. Enter the following to set the setup logical variable on to indicate a tuning process is underway:

```
svar fs_setup ON
```
5. Enter the following to set the idle time to 10 seconds to avoid having to wait for it during the tuning process:

```
svar smk_idle_tm 10
```
6. Enter the following to set the maximum number of cycles to 1 so only one smoke cycle is executed each time the general-purpose test sequence is started:

```
svar smk_max_cyc 1
```
7. Enter the following to start the test cycle:

```
nt gp_fed_smoke
```

Refer to cyflex.com usage help for [nt](#) for related information.
8. Tune the transient controls variables by using the strip chart and running the federal smoke test procedure. Compare the actual speed to the reference speed. Keep the speed error as close to zero and possible.
9. Review the cycle report (`/data/fed_smoke/cell.test.rep.cycle`) to ensure the cycle is valid. Repeat the cycle/tuning process until a valid cycle is achieved.
10. Enter the following to set the idle time to 5 minutes (=300 seconds):

```
svar smk_idle_tm 300
```
11. Enter the following to set the maximum number of cycles to the desired number of cycles:

```
svar smk_max_cyc <desired num cycles>
```

12. Enter the following to set the setup logical variable off to indicate a tuning process is complete:

```
svar fs_setup OFF
```

13. Enter the following to start the test cycle:

```
nt gp_fed_smoke
```

14. Wait for the desired number of cycles to run.

15. Review the output reports.

2.1 Sample Output Reports

The following sub-sections list examples of federal smoke test output reports.



2.1.1 Federal Smoke Cycle Report

* * Federal Smoke Cycle Report - Test 55 Cycle 1

Test Cell: 6 2/24/2005 8:52:26 assetx v4.8

Smoke File: smk.6.55.87.1 PAM: Q19_audit2559.45
 GP Test:

SMOKE AVERAGES:

| | Measured | Corrected | EPA Rounding |
|-----|----------|-----------|--------------|
| A | 13.5 | 14.0 | 14.021 |
| B | 7.1 | 7.4 | 7.373 |
| C | 21.1 | 21.8 | 21.850 |
| PSC | 13.3 | 13.8 | |

Correction Factor: 1.043 (from optical path of 5.8 [in] to 6.0 [in])

SPEED TABLE:

| Mode (HP) | Speed | | | Mode Duration | Speed | Linearity | | Final | |
|--------------|-------|--------|------|------------------|-------|-----------|-------|-------|------|
| | Final | Target | Pass | | | Time | Power | | |
| Target | | | | | | | | | |
| Idle | 749 | 750 | Pass | 303.8 | Pass | | 0.00 | Pass | |
| Accel 1 | 961 | 950 | Pass | 2.3 | | | 0.00 | Pass | |
| Accel 2 | 1545 | 1530 | Pass | 5.6 | Pass | 62 | Pass | 0.00 | Pass |
| Decel | 1328 | 1300 | Pass | 1.0 | | | 0.00 | Pass | |
| Accel 3 | 1712 | 1710 | Pass | 9.2 | Pass | | 0.00 | Pass | |
| Transition | 1747 | 1750 | Pass | 52.9 | Pass | 1794 | Pass | 0.00 | Pass |
| 764 | Pass | | | | | | | | |
| Lug Down | 1298 | 1300 | Pass | 36.2 | Pass | 30 | Pass | 0.00 | Pass |
| IdleReturn | 718 | 750 | Pass | 1.4 | Pass | | 0.00 | Pass | |

RESPONSE TEST RESULTS:

Response = 85.85
 Sampling Interval = 0.05 [sec]
 Number of Datapoints = 113

Total Rotary Inertia = 995.5 [lb]
Initial Speed = 966 [rpm]
Final Speed = 1545 [rpm]

2.1.2 Federal Smoke Development Report

* * Federal Smoke Cycle Report - Test 55 Cycle 1

Test Cell: 6 2/24/2005 8:52:26 assetx v4.8

Smoke File: smk.6.55.87.1 PAM: Q19_audit2559.45 GP Test:

SMOKE SCAN MAXIMA:

| | Accel | | Lugdown | | Peak | | Short Cycle | |
|----|-------|------|---------|------|------|------|-------------|------|
| | Meas | Corr | Meas | Corr | Meas | Corr | Meas | Corr |
| 1 | 23.5 | 24.4 | 7.3 | 7.6 | 23.5 | 24.4 | 23.5 | 24.4 |
| 2 | 21.0 | 21.8 | 7.2 | 7.5 | 21.0 | 21.8 | 15.4 | 16.0 |
| 3 | 18.6 | 19.3 | 7.0 | 7.3 | 18.6 | 19.3 | 14.7 | 15.3 |
| 4 | 15.4 | 16.0 | 7.0 | 7.3 | | | 14.7 | 15.3 |
| 5 | 14.7 | 15.3 | 6.9 | 7.2 | | | 13.5 | 14.1 |
| 6 | 14.7 | 15.3 | | | | | 12.6 | 13.1 |
| 7 | 13.5 | 14.1 | | | | | 12.1 | 12.6 |
| 8 | 12.6 | 13.1 | | | | | 11.0 | 11.4 |
| 9 | 12.1 | 12.6 | | | | | 10.4 | 10.8 |
| 10 | 11.0 | 11.4 | | | | | 9.6 | 10.0 |
| 11 | 10.4 | 10.8 | | | | | 8.5 | 8.8 |
| 12 | 9.6 | 10.0 | | | | | | |
| 13 | 8.7 | 9.0 | | | | | | |
| 14 | 8.5 | 8.8 | | | | | | |
| 15 | 7.8 | 8.2 | | | | | | |

SMOKE SCANS:

| Test Time | Mode | Smoke | | Speed [rpm] | Torque [lb-ft] | Gross_torq [lb-ft] |
|-----------|------|-------|------|-------------|----------------|--------------------|
| | | Meas | Corr | | | |
| 0.5 | 0 | 4.57 | 4.76 | 757 | 154 | 448.2 |
| 1.0 | 0 | 4.49 | 4.68 | 755 | 215 | -278.3 |
| 1.5 | 0 | 4.37 | 4.55 | 747 | 198 | -576.6 |
| 2.0 | 0 | 4.24 | 4.42 | 747 | 205 | 47.8 |
| 2.5 | 0 | 4.75 | 4.95 | 755 | 190 | 502.4 |
| 3.0 | 0 | 4.57 | 4.76 | 752 | 190 | 604.1 |
| 3.5 | 0 | 4.43 | 4.62 | 747 | 175 | 374.2 |
| 4.0 | 0 | 4.51 | 4.70 | 753 | 110 | 262.4 |
| 4.5 | 0 | 4.47 | 4.66 | 753 | 148 | 241.6 |
| 5.0 | 0 | 4.44 | 4.63 | 759 | 101 | 194.7 |
| 5.5 | 0 | 4.16 | 4.33 | 762 | 135 | -364.4 |
| 6.0 | 0 | 4.39 | 4.57 | 755 | 110 | 196.0 |
| 6.5 | 0 | 4.39 | 4.57 | 748 | 146 | 145.1 |
| 7.0 | 0 | 4.27 | 4.45 | 758 | 147 | 155.8 |
| 7.5 | 0 | 4.44 | 4.63 | 750 | 142 | 840.1 |



| | | | | | | |
|------|---|------|------|-----|-----|--------|
| 8.0 | 0 | 4.36 | 4.54 | 747 | 117 | -385.5 |
| 8.5 | 0 | 4.30 | 4.48 | 746 | 165 | 174.4 |
| 9.0 | 0 | 4.30 | 4.48 | 745 | 168 | -386.4 |
| 9.5 | 0 | 4.46 | 4.65 | 754 | 148 | 148.0 |
| 10.0 | 0 | 4.45 | 4.64 | 747 | 183 | -197.3 |
| 10.5 | 0 | 4.25 | 4.43 | 746 | 128 | -5.3 |

2.1.3 Federal Smoke Test Summary Report

* * Federal Smoke Cycle Summary - Test 55

Test Cell: 6 2/24/2005 9:06:39 assetx v4.8

Engine Serial: 37215987 Model: QSK19 Tier 1 LTA

PAM: Q19_audit2559.45 GP Test:

Rated Power: 685 [hp] Rated Speed: 1800 [rpm] Idle Speed: 750 [rpm]

FEDERAL SMOKE RESULTS:

| Units | Cycle 1 | | Cycle 2 | | Cycle 3 | | Average | | |
|-----------|---------|------|---------|------|---------|------|---------|------|----|
| | Meas | Corr | Meas | Corr | Meas | Corr | Meas | Corr | |
| A opac] | 13.489 | 14.0 | 12.517 | 13.0 | 12.770 | 13.3 | 12.925 | 13.4 | [% |
| B opac] | 7.080 | 7.4 | 6.982 | 7.3 | 6.629 | 6.9 | 6.897 | 7.2 | [% |
| C opac] | 21.052 | 21.8 | 19.236 | 20.0 | 19.839 | 20.6 | 20.042 | 20.8 | [% |
| PSC opac] | 13.289 | 13.8 | 12.138 | 12.6 | 12.477 | 13.0 | 12.634 | 13.1 | [% |

Smoke Meter Type: 1

Correction Factor: 1.043 (from optical path of 5.8 [in] to 6.0 [in])

EPA Intermediate Speed: 1300 [rpm]

TEST RUN

| Channels | Values | Valid Range |
|--------------------|----------------------|---------------------------------|
| Inlet Air Temp: | 74.0 - 78.0 [deg_f] | |
| Fuel Inlet Temp: | 95.4 - 114.0 [deg_f] | <= Fail => 90.0 - 110.0 [deg_f] |
| Throttle Position: | 0 - 100 [%] | |
| Barometer: | 29.39 [in_hg] | |
| Vapor Pressure: | 0.482 [in_hg] | |

RESPONSE TEST RESULTS

| Units | Cycle 1 | Cycle 2 | Cycle 3 | Average |
|---------------|---------|---------|---------|---------|
| Response % | 85.9 | 82.3 | 85.4 | 84.5 |
| [%] | | | | |
| Datapoints | 113 | 101 | 110 | 108 |
| Initial Speed | 966.0 | 967.0 | 965.0 | 966.0 |
| [rpm] | | | | |



| | | | | |
|---------------|--------|--------|--------|--------|
| Final Speed | 1545.0 | 1532.0 | 1537.0 | 1538.0 |
| [rpm] | | | | |
| Measured Idle | 749.3 | 749.4 | 749.4 | 749.4 |
| [rpm] | | | | |
| Speed | | | | |

Sample Interval: 0.05 [sec]
 Total Rotary Inertia: 995.5 [lb]

PUBLISHED ENGINE DATA

| | | |
|-------------|-------|---------|
| Torque Peak | Rated | |
| 1300 | 1800 | [rpm] |
| 2200 | 2000 | [lb_ft] |
| 545 | 685 | [hp] |

Engine Serial: 37215987
 Model: QSK19 Tier 1 LTA
 Displacement: 1150.0 [in3]
 Exhaust Diameter: 6.0 [in]

3 General Purpose Test Cycle

Use the `gp_test` cycle `gp_fed_smoke` to manage the federal smoke test. Refer to *Section 3.1 General Purpose Test Scheduler Cycle Specification* on page 9.

Table 1 provides an overview of the cycle sections. *Table 2* provides an overview of the `gp_test` modes. Each mode has a defined speed profile and dyno and throttle control mode.

Table 1: General Purpose Test Cycle Sections

| Section | Description |
|---------------|--|
| Speed | The first (top-most) section identifies the speed profile of the test on a mode by mode basis. It also identifies threshold crossing points which result in mode transitions. |
| Modes | The second section provides information about the mode's purpose, duration, and mode numbers. The numbers associated with each mode are in the format x:y, where x is the <code>gp_test</code> mode number for the mode, and y is the federal smoke cycle section number for the mode. |
| Dyno | The third section provides information about the control of the dyno, including open loop and closed loop operation and open loop commands. |
| Throttle | The fourth section provides information about the control of the throttle, including open loop commands and transitions. |
| Miscellaneous | The fifth section shows other information associated with achieving the control required for the test. |

Table 2: General Purpose Test Modes

| Section | Description |
|---------|--|
| Mode 3 | Engine at idle: Open loop throttle command of 0%. Open loop dyno command of 0%. Mode 3 lasts 5 minutes for a compliant federal smoke cycle but may be shortened using the advance command or setting the variable <code>smk_idl_tim</code> to the desired value. Dyno water flow is removed at the start of the idle mode to reduce loading. |
| Mode 11 | Breakover: Open loop throttle command of <code>th1</code> . Open loop dyno command of 0%. Mode 11 lasts until engine speed exceeds 50 RPM over the average speed observed during the idle mode. Dyno water flow is activated at the start of the mode to provide loading during the breakover and in subsequent modes. |
| Mode 21 | Idle + 200 RPM: Open loop throttle command of <code>th1</code> . Open loop dyno command of 0%. Mode 21 lasts until engine speed exceeds 200 RPM over the average speed observed during the idle mode. |
| Mode 22 | Acceleration Pre-load: Open loop throttle command of <code>th1</code> . Open loop dyno command of <code>dy1</code> . Mode 22 lasts for <code>t1</code> seconds. |
| Mode 31 | Acceleration: Open loop throttle command of 100%. Mode 31 lasts until the speed error is 0. |

| Section | Description |
|---------|---|
| Mode 32 | Acceleration: Open loop throttle command of 100%. Dyno closed on speed. Speed ramping from the speed at mode start to rated speed. Mode 32 lasts until the speed exceeds 85% of rated speed. |
| Mode 41 | Deceleration: Open loop throttle command of 0%. Open loop dyno command of dy2. Mode 41 lasts for t2 seconds. |
| Mode 42 | Deceleration: Open loop throttle command of 0%. Open loop dyno command of dy3. Mode 42 lasts until speed drops below intermediate speed plus s1. |
| Mode 43 | Deceleration: Open loop throttle command of 0%. Open loop dyno command of dy4 ramping to 0% over 1 second. Mode 43 lasts until speed drops below intermediate speed. |
| Mode 51 | Acceleration: Open loop throttle command of 100%. Open loop dyno command of 0%. Mode 51 lasts until speed exceeds intermediate speed plus s2. |
| Mode 52 | Acceleration: Open loop throttle command of 100%. Dyno closed on speed, dyno PID gains adjusted, dyno feed-forward active using speed reference. Mode 52 lasts until speed exceeds 95% of rated speed. |
| Mode 61 | Rated Speed Transition: Open loop throttle command of 100%. Dyno closed on speed, with rated speed as a target. Dyno PID gains adjusted, dyno feed-forward active using speed reference. Mode 61 lasts until speed achieves rated speed within 50 RPM for 5 seconds. |
| Mode 71 | Rated Speed: Open loop throttle command of 100%. Dyno closed on speed, with rated speed as a target. Dyno PID gains adjusted, dyno feed-forward deactivated. Mode 71 lasts for 50 seconds. |
| Mode 72 | Lugging: Open loop throttle command of 100%. Dyno closed on speed, with speed target ramping from rated to intermediate speed over 35 seconds. Mode 72 lasts until speed drops below 50 RPM above intermediate speed. |
| Mode 81 | Lugging: Open loop throttle command of 100%. Dyno closed on speed, with speed target of intermediate speed. Mode 81 lasts for 35 seconds less the amount of time spent in mode 72. Upon mode termination control is returned to mode 3 or idle depending on the number of cycles to be performed. |

3.1 General Purpose Test Scheduler Cycle Specification

```

# Federal smoke
#
# Purpose: To apply the federal smoke cycle per SAE J35, Sept. 1988 Revision
#

#start_mode ( mode where the test begins )
    1

#####
# @GLOBAL_EVENTS specify events that are handled the same
# regardless of which test mode is active.
#
# If neither the "next_mode" or the "test_procedure" are specified, then
# the mode is just terminated and the normal path is taken.
#
# If the "next_mode" is specified, but the "test_procedure" is not,
# then the test will jump to that mode in this procedure.
#
# If the "test_procedure" is specified, but the "next_mode" is not,
# then the test will jump to that sub-procedure. If the sub-procedure
# exits via a RETURN, the the current procedure will begin executing
# at the "default_next_mode" specified for the test mode that was
# interrupted.
#
# If both "next_mode" and "test_procedure" are specified, it will jump
# to the "next_mode" upon returning from the procedure. If the
# "test_procedure" file does not exist or cannot be opened, then this
# mode will be executed next.

@GLOBAL_EVENTS
#event_name          next_mode          test_procedure
    emergency         -                /specs/gp/gp_emergency
    abort_limit       -                /specs/gp/gp_shutdown

@REGISTERED_EVENTS
    stop_test         -                /specs/gp/gp_shutdown
    idle_mode         90

#
#-----
#
@MODE
#mode_number          timeout(seconds)  next_mode
    1                  10.[sec]         2
    Start up required services

@BACKGROUND_TASK
#start code          background command string
    AT_START          "/asset/bin/fedSmokeHdr log_r_specs.fsr"

# Set the event to have floger exit if it is still running
@SET_EVENTS

```

```
# start type          event name
  AT_START            rels_it

@PARAMETERS
#start_type label          value      restore(YES/NO)
  AT_START   smk_cycle     0[none]   NO
#
#-----
#
@MODE
#mode_number      timeout(seconds)      next_mode
  2                5.[sec]                3
  Start up required services

@BACKGROUND_TASK
#start code      background command string
  AT_START       "/asset/bin/floger /specs/logr_specs.fsr"
```



```
#####
# Paragraph 7.1 - Idle the engine for 5 - 5.5 minutes at manufacturer's
#                   recommended curb idle speed. Dynamometer load may be applied
#                   to simulate an automatic transmission to achieve curb idle
#                   speed. Any other adjustments that cause curb idle speed to
#                   be altered for the purpose of simulating accessories are not
#                   allowed.
#####
#-----
#
#
@MODE
#mode_number      timeout(seconds)      next_mode
   3                "smk_idle_tim"                6
   Curb idle

@ENGINE_CONTROL_MODE
   4

@DYNO
#OPEN/CLOSED_LOOP  target(%)
   OPEN_LOOP        0[%]

@THROTTLE
#OPEN/CLOSED_LOOP  target(%)
   OPEN_LOOP        0[%]

@PARAMETERS
#start_type label          value          restore(YES/NO)
   AT_START    Fed_Smoke_Md  0[none]        NO
   AT_START    TestFailed    FALSE          NO
   AT_START    Dyn_H2O_dis    ON             YES
   AT_START    Dyno_FF        0[%]          NO

@SET_EVENTS
# start_type      event_name
   AT_START        start_it

@STABILITY_ACTION
   NONE

@STABILITY_SPECS
#type_code label      timeout      rate      reference      tolerance min_ref
   TIME_DELAY -      4.8[min]

#-----
#
#
@MODE
#mode_number      timeout(seconds)      next_mode
   11                0[sec]                21
   Apply throttle

@THROTTLE
#OPEN/CLOSED_LOOP  target(%)
   OPEN_LOOP        th1
```



@PARAMETERS

| #start_type | label | value | restore(YES/NO) |
|-------------|--------------|---------|-----------------|
| AT_START | Dyn_H2O_dis | OFF | NO |
| AT_START | Fed_Smoke_Md | 1[none] | NO |

@LIMIT_SPECS

| #variable | value | Upper/Lower_type | proc_int(FAS/MED/SLO) | else_mode |
|-----------|------------------------|------------------|-----------------------|-----------|
| RPM | "Idle_Speed + 20[RPM]" | U | FAS | - |



```
#####
# Paragraph 7.2.1 First Accel: Represented by points A, B, and C on the
#
#           chart.
#
#           Point A is where the first increase over curb idle speed
#           occurs (typically defined as 5-10 RPM above the average
#           observed idle speed). Point B is the event where the
#           throttle begins to open to full position. Point C is where
#           the throttle reaches a fully open position and must occur
#           within 1 second of point B.
#
#           By partially opening the throttle, increase the speed to
#           200 +/- 50 RPM above observed curb idle speed, measured at
#           point B. The speed between points A nd B should not exceed
#           50 RPM above that at point B. Total time measured between
#           points A and C should not exceed 3 seconds.
#
# Mode description - accelerate from idle to 200 RPM in two seconds with no
#                   load.
#
# Note: if automatic transmission needs to be simulated, use torque converter
#       load simulator and change dyno to closed loop.
#
#-----
#
@MODE
#mode_number  seconds          next_mode
    21          "2.5[sec]-t1"      22
    First accel to idle + 200 RPM in 2.5 seconds

@PARAMETERS
#start_type label          value      restore(YES/NO)
AT_START    Dyn_H2O_dis    OFF        NO
AT_START    Fed_Smoke_Md   2[None]    NO

@LIMIT_SPECS
#variable      value          Upper/Lower_type  proc_int(FAS/MED/SLO) else_mode
RPM           "Idle_Speed + 200[RPM]"    U                FAS                -

# Mode description - apply the dyno preload to prepare for the throttle
# snap
#
# Note: if automatic transmission needs to be simulated, use
# torque converter load simulator and change dyno to closed loop.
#
#-----
#
@MODE
#mode_number  seconds          next_mode
    22          t1              31
    Preload Dyno

@DYNO
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      dy1
```



```
#####
# Paragraph 7.2.2 Second Accel: Beginning at point C with full throttle,
#
#       allow the engine to accelerate against inertia or a
#
#       dynamometer load such that the engine speed is increases to
#
#       at least 85% of rated speed. Point D is defined as 85% of
#
#       rated speed. The acceleration between points C and D shall
#
#       be kept linear within +/- 100 RPM, and the total time
#
#       measured between points C and D shall be 5 +/- 1.5 seconds.
# Mode description - open throttle to full - maintain dyno preload
@MODE
#mode_number    seconds          next_mode
    31            0[sec]           32
    Full throttle accel to 85% of rated speed - preload applied.

@THROTTLE
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      100[%]

@DYNO
#OPEN/CLOSED_LOOP  target(%)
    CLOSED_LOOP

@SPEED
#start_target      end_target      Ramp Rate
# Speed we're at   Rated
    RPM             Rated_Speed "(Rated_Speed-RPM)/5[sec]"

@PARAMETERS
#start_type        label          value          restore(YES/NO)
AT_START           Fed_Smoke_Md   3[None]        NO

@LIMIT_SPECS
#variable          value          Upper/Lower_type  proc_int(FAS/MED/SLO) else_mode
    Speed_ERR      0[RPM]         L                FAS                -

# Mode description - open throttle to full, set speed control to ramp from
# idle + 200 to rated speed in 6.5 seconds. End mode when 85% of rated speed
# is achieved.
#-----
@MODE
#mode_number    seconds          next_mode
    32            "5[sec]-t2"       41
    Full throttle accel to 85% of rated speed.

@DYNO
#OPEN/CLOSED_LOOP
    CLOSED_LOOP

@LIMIT_SPECS
#variable          value          Upper/Lower_type  proc_int(FAS/MED/SLO) else_mode
RPM                "0.85[None]*Rated_Speed"  U                FAS                -

@PARAMETERS
#start_type        label          value          restore(YES/NO)
    AT_START       Fed_Smoke_Md   3[None]        NO
```



```
#####
# Paragraph 7.2.3 Deceleration: Beginning at Point E, rapidly move the
# throttle to, and hold in, the closed position. Point E is
# defined as any speed after Point D (7.22), but is recommended
# not to exceed 95% of rated speed. Apply the required load to
# decelerate the engine to intermediate speed +/- 50 RPM,
# measured at Point F which is the event where the throttle
# begins to reopen in preparation for the next accel mode
# (7.2.4). The fully opened throttle position is designated
# as point G. The deceleration time from Point D to G shall be 2
# +/- 1.5 s for electric dynamometers only.

# Mode description - fully close throttle, set speed control to ramp from 85
# % rated to intermediate speed in 2 seconds. End mode when intermediate
# speed is achieved.
#
#-----
#
@MODE
#mode_number    seconds    next_mode
    41            t2         42
    Closed throttle, speed ramping to intermediate speed.

@THROTTLE
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      0[%]

@DYNO
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      dy2

@PARAMETERS
#start_type    label            value    restore(YES/NO)
    AT_START    Fed_Smoke_Md    4[None]    NO

#
#-----
#
#####
@MODE
    0[sec]        43
    sed throttle, speed ramping to intermediate speed.

@DYNO
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      dy3

@LIMIT_SPECS
#variable    value    Upper/Lower_type    proc_int(FAS/MED/SLO) else_mode
RPM          "Intrmd_Speed+s1"    L            FAS            -
#
#-----
#
@MODE
#mode_number    seconds    next_mode
```

```

43                0[sec]                51
Closed throttle, speed ramping to intermediate speed.

```

```
@DYNO
```

```
#OPEN/CLOSED_LOOP  target(%)
OPEN_LOOP          dy4
```

```
@LIMIT_SPECS
```

```
#variable      value      Upper/Lower_type      proc_int(FAS/MED/SLO)  else_mode
RPM            Intrmd_Speed      L                      FAS                    9
```

```
#
```

```
#-----
```

```
#
```

```
@MODE
```

```
#mode_number  seconds      next_mode
51            1[sec]      52
Set Dyno Command to 0 %
```

```
@PARAMETERS
```

```
#start_type  label          value      restore(YES/NO)
AT_START     Fed_Smoke_Md    5[None]    NO
```

```
@DYNO
```

```
#OPEN/CLOSED_LOOP  target(%)
OPEN_LOOP          0[%]
```




```
#####
# Paragraph 7.2.4 Third Accel: Beginning at point G, fully open throttle, the
#       dynamometer load shall be adjusted to control the acceleration
#       rate so that the engine speed increase to rated speed. The
#       time duration between points G and H (defined as 95% of rated
#       speed) shall be 10 +/- 2 seconds.
# Mode description - fully open throttle, set speed control to ramp from
# intermediate speed to rated speed 10 seconds. End mode when rated speed is
# achieved.
#
#-----
#
@MODE
#mode_number    seconds          next_mode
    52           0[sec]           53
    Full throttle accel to intermediate + s9

@THROTTLE
#OPEN/CLOSED_LOOP  target(%)
    OPEN_LOOP      100[%]

@LIMIT_SPECS
#variable        value          Upper/Lower_type  proc_int(FAS/MED/SLO) else_mode
    RPM           "Intrmd_Speed+s2"      U                FAS                -
#
#-----
#
#####
@MODE
#mode_number    seconds          next_mode
    53           10[sec]         61
    Full throttle accel to rated speed in 10 seconds.

@DYNO
#OPEN/CLOSED_LOOP  target(%)
    CLOSED_LOOP

@FEED_FORWARD
#loop            active_flag    FF_label    gain
    DYNO_CTRLER   ON            Dyno_FF     1.0

@SPEED
#start_target    end_target
# Intermediate    Rated
    RPM           Rated_Speed

@PID_GAINS
#gain_set
    DYNO_SPEED_GAINS    Prop    Integral    Derivative
                        -.10    -.010    -0.01

@LIMIT_SPECS
#variable        value          Upper/Lower_type  proc_int(FAS/MED/SLO) else_mode
RPM           "0.95[none]*Rated_Speed"      U                FAS                -
```

```
#
#-----
#
@MODE
#mode_number    seconds    next_mode
    61            0[sec]      71
    Transition ramp

@PARAMETERS
#start_type label          value    restore(YES/NO)
AT_START    Fed_Smoke_Md    6[None]    NO

@STABILITY_ACTION
MODE_TERMINATE

@STABILITY_SPECS
#type_code label  timeout  rate  reference          tolerance  min_ref
DEVIATION  RPM    5[sec]  FAS   "Rated_Speed"     50
```



```
#####
# Paragraph 7.3 Rated Speed Mode: Represented by points H and I.
#
#           Immediately upon completion of the preceding (7.24) third
#           accel mode at point H, adjust the dynamometer controls to
#           permit the engine to develop rated break power. The engine
#           should operate within +/- 5% of rated brake power observed
#           during preconditioning mode (6.5) and within +/- 50 rpm of
#           rated speed during the last 10 sec of this mode. Near the end
#           of this mode, it is necessary to reduce engine speed by
#           increasing dynamometer load to prepare for the lugging mode
#           as defined in 7.4. Point I defines the end of this mode and
#           occurs when the speed is 50 rpm less than the manufacturer's
#           specified rated speed. Total time between H and I should be
#           55 +/- 5 seconds.
#
#-----
#
# Mode description - fully open throttle, hold speed at rated speed. Hold
# mode for 50 seconds.
@MODE
#mode_number    seconds          next_mode
    71            50[sec]           72
    Rated speed, full throttle

@FEED_FORWARD
#loop            active_flag      FF_label    gain
    DYNO_CTRLER      OFF                Gross_torq  .002

@PID_GAINS
#gain_set              Prop          Integral      Derivative
    DYNO_SPEED_GAINS  -.08          -.008         0.0

@PARAMETERS
#start_type label          value        restore(YES/NO)
    AT_START    Fed_Smoke_Md    7[None]      NO
    AT_START    Dyno_FF        0[%]         NO
```

```

#####
# Paragraph 7.4 Lugging Mode:
#
#           Beginning at point I, with the throttle remaining in the
#           fully open position, adjust the dynamometer controls to
#           gradually slow the engine down to intermediate speed over
#           a period of 35 +/- 5 sec, marked by point J, as the end point
#           of the lugging mode. The lug down speed between points I
#           and J shall be linear within +/- 100 rpm. Point J is the
#           beginning of the idle mode (7.1) for the next cycle.
#
#-----
#
# Mode description - fully open throttle, ramp speed to intermediate speed
# over 35 seconds.
@MODE
#mode_number  seconds          next_mode
    72          35[sec]          81
    Full throttle, speed ramping to intermediate.

@SPEED
#start_target  end_target
# Rated        Intermediate
    Rated_Speed  Intrmd_Speed

@LIMIT_SPECS
#variable      value          Upper/Lower_type  proc_int(FAS/MED/SLO)  else_mode
    RPM         "Rated_Speed-50[RPM]"  L                  FAS                    -

@PARAMETERS
#start_type  label              value          restore(YES/NO)
    AT_START  time_72          time           NO
    AT_END    time_72          "time-time_72" NO
#
#-----
#
@MODE
#mode_number  seconds          next_mode
    81          "35[sec]-time_72"  3
    Full throttle, speed ramping to intermediate.

@PARAMETERS
#start_type  label              value          restore(YES/NO)
    AT_START  Fed_Smoke_Md  8[None]       NO

@SPEED
#start_target  end_target
# Rated        Intermediate
    RPM         Intrmd_Speed

@SET_EVENTS
# start_type  event_name
    AT_END    stop_it

```



```

@PARAMETERS
#start_type      label          value      restore(YES/NO)
  AT_START      Fed_Smoke_Md    8[None]    NO

#
#-----
#
#####
@MODE
#mode_number  seconds          next_mode
  90    0[sec]    90
  idle - safe mode ( not fuel readings, history log every 30

@ENGINE_CONTROL_MODE
  4

@DYNO
#OPEN/CLOSED_LOOP  start_target(%)  end_target(%)
  OPEN_LOOP        0[%]            0[%]

@THROTTLE
#OPEN/CLOSED_LOOP  start_target(%)  end_target(%)
  OPEN_LOOP        0[%]            0[%]

@PARAMETERS
  #start_type label          value      restore(YES/NO)
  AT_START    enab_lwr_lmt    OFF        NO
    
```

4 Transient Control Tuning

The federal smoke cycle includes transient operating conditions that have linearity and time response requirements. The test cycle has been developed to provide some control flexibility in order to meet these transient requirements. This section provides an overview of these features and how to use them.

The transient control tuning features are implemented through the use of variables that have values that may be established by the test operator. The variables provide the following types of functionality:

- Open loop dyno commands.
- Open loop throttle commands.
- Timing control for mode durations.
- Speed thresholds for mode changes.

The variables may be set by the test system operator by observing the system response and using the suggestions identified below for setting up each variable. The set command is used to actually set the value of the variable. A variable's value may be permanently set by modifying the general usage variables specification file `gen_labels.nnn`. The specifications for these real variables are provided in *Appendix A. General Usage Variable Specifications* on page 29.

4.1 Tunable Variables

Table 3 describes the tunable variables.

Table 3: Tunable Variables

| Variable | Description |
|----------|---|
| th1 | The open loop throttle command required to transition from idle to idle + 200 RPM in 2.5 seconds, set in <code>gp_test</code> mode number 11 and maintained through mode number 22. The value of th1 should be increased if engine speed does not achieve idle speed + 200 RPM in 2.5 seconds. The value of th1 should be decreased if the engine speed resulting from the throttle command increases at too high a rate resulting in the inability to achieve linear ramping in the subsequent test modes. |
| dy1 | The open loop dyno command used to preload the dyno in preparation for the throttle snap which occurs at the start of <code>gp_test</code> mode number 31. This dyno command is applied at the start of the <code>gp_test</code> mode number 22 and maintained through <code>gp_test</code> mode number 31. The method of setting dy1 will be discussed with variable t1. |

| Variable | Description |
|--------------|---|
| t1 | The amount of time to apply $\text{dy}1$ prior to the throttle snap which occurs at the start of <code>gp_test</code> mode 31. The value of $t1$ should not exceed 2 seconds. The values of $\text{dy}1$ and $t1$ should be set collectively to ensure the first acceleration ramping in <code>gp_test</code> mode numbers 31 and 32 is linear and corresponding to the speed reference. If the actual speed leads (is faster to increase than the reference) then more pre-loading is required. This may be accomplished by a combination of increasing $\text{dy}1$ and/or $t1$. If the actual speed lags the reference then less preloading is required. This may be achieved by a combination of reducing $\text{dy}1$ and/or $t1$. |
| $\text{dy}2$ | The first open loop dyno command used to decelerate the engine following the throttle chop at the start of <code>gp_test</code> mode number 41. This value is typically 0% but may be increased to achieve a faster deceleration if required. |
| $\text{dy}3$ | The second open loop dyno command used to decelerate the engine in <code>gp_test</code> mode number 42. This value is used to control how long the deceleration to intermediate speed + $s1$ is to take. There are no requirements on how long this time is when an absorbing-only dyno is used. |
| $s1$ | The delta speed over intermediate speed serves as a threshold which drives the transition from <code>gp_test</code> mode number 42 to <code>gp_test</code> mode number 43. This value is set to allow enough time for the dyno open loop command from $\text{dy}3$ to $\text{dy}4$. |
| $\text{dy}4$ | The third open loop dyno command used to decelerate the engine in <code>gp_test</code> mode number 43. This value is used to control how long the deceleration from intermediate speed + $s1$ to intermediate speed is to take. There are no requirements on how long this time is when an absorbing-only dyno is used. |
| $s2$ | The delta speed over intermediate speed serves as a threshold which drives the transition from <code>gp_test</code> mode number 52 to <code>gp_test</code> mode number 53. This defines when dyno feed-forward is to be applied and when an adjustment of the dyno-speed PID gains is to be activated. |

5 Data Logging

The mechanism used to acquire data during the federal smoke cycle is the data logger task `flogger`. This task is configured to acquire data at 10 Hz for the duration of each individual cycle, from the start of `gp_test` mode 3 through the end of `gp_test` mode 81. The channels of data acquired during the test are:

- Federal Smoke Section Number
- Engine Speed
- Speed Error
- Dyno Torque
- Smoke
- Fuel Inlet Temperature
- Air Inlet Temperature
- Throttle Command

These channels are required for the test results to be analyzed and reported. The data logging task may be modified to include additional channels as desired by the test users. The data logger task's specifications are in a file called `logr_spec.fsr`. Refer to *Section 5.1 Logger Specification* below for an example.

The data logging task generates a data log file located in the directory `/data/PC_format`. The file contains engine and test scalar information required to analyze the data located at the top of the file. The remainder of the file contains the values of the channels acquired during the test. An example of a data file, which has been truncated, is provided in *Section 5.2 Data Logger Output File* on page 26.

Refer to the following for related information:

- [Fast Data Logger Application User Guide](#)
- cyflex.com usage help for `flogger`

5.1 Logger Specification

```
@DESCRIPTION
# Computed expressions may be entered. Description goes in output
file
    'fedSmokeHdr Test          TC6'

@FILENAME

# Computed expressions may be entered. The logger data file name is
# constructed dynamically from the root and the three variables. The 3
file is stored in the path /data/PC_format

    "'smk.6.'" + smk_test + '.' + smk_repeat + '.' + smk_cycle"

@SCAN_INTERVAL
# time between scans eg. 1[sec] Computed expressions may be
entered
```



```

50[msec]

@MAX_SCANS
    # The maximum number of times to sample
    36000

@RELEASE_EVENT
    # Any existing event name may be entered.
    rels_it

@STOP_EVENT
    # Any existing event name may be entered.
    stop_it

@START_EVENT
    # Any existing event name may be entered.
    start_it

@PACKED
    # Should output be comma separated? (yes,no)
    YES

@FEDERAL_SMOKE
    /specs/logr_specs.fsr

#-----#
#           "DO NOT"
#   Change First 8 Channels or an error will result in fedSmokeRep
#       Required Channels for Federal Smoke Cycle Report
#       lines 1-8 (test mode - thr pos) are required
#-----#
@SCAN_LIST
    # ASSET/Cyflex variable label[opt units] [opt format or statistical
member]
    Fed_Smoke_Md
    ANA_spd
    ANA_spd_ER
    ENG_TORQ
    opac_R
    fpmp_inT
    lcmp_inT_R
    Throt_real

#-----#
# DO Not Change Ninth Channel for DUAL BANK ENGINE
# Required Channel for Federal Smoke Cycle Report LEFT Bank
#-----#
#   line 9 is required for dual bank
#opac_L

```

```

#-----#
# Optional Channels
# variables and order of variables must appear in Test Plan
#-----#

Throttle_CM
int_mnfP_R
int_mnfT
lcmp_inP_R
exh_stkP_R
dyno_CM

```

5.2 Data Logger Output File

```

$HEADER
  1  date:                11/5/2004                [none]
  2  time:                14:07:39                [none]
  3  sample interval:    0.05                    [sec]
  4  test cell:          6                        [none]
  5  emissions cart:     27                       [none]
  6  test:               55                       [none]
  7  repetition:        32                       [none]
  8  cycle:              1                        [none]
  9  PAM datapoint:     Tier3Beta2Q.107           [none]
 10  operator:          Schlatterer              [none]
 11  vapor pressure:    0.400                    [in_hg]
 12  barometer:         29.46                    [in_hg]
 13  rated speed:       2000                      [rpm]
 14  rated torque:      1838                      [lb_ft]
 15  torque peak speed: 1500                      [rpm]
 16  peak torque:       2200                      [lb_ft]
 17  idle speed:        700                      [rpm]
 18  high idle speed:   2400                      [rpm]
 19  engine model:      Q19_T2 Air to Air         [none]
 20  engine serial:     37212770                [none]
 21  engine hours:      43.9                     [hr]
 22  displacement:     1150.0                    [in3]
 23  total inertia:     889.4                    [lb]
 24  meter type:        1                        [none]
 25  meter diameter:    6.00                     [in]
 26  meter constant:    1.043                    [none]
 27  optical path:      5.75                     [in]
 28  filter calibration date: 1/1/80                [none]
 29  exhaust pipe diameter: 6.0                    [in]
 30  motoring dyno:     no                       [none]
 31  Brake HorsePower:  719.0                    [HP]

$CHANNELS
  0  data channels:      26                        [none]
  1  channel 1:         test_time                [sec]
  2  channel 2:         Fed_Smoke_Md            [none]

```



```

3 channel 3: ANA_spd [rpm]
4 channel 4: ANA_spd_ER [rpm]
5 channel 5: ENG_TORQ [LB_FT]
6 channel 6: opac_R [%_OPAC]
7 channel 7: fpmp_inT [deg_F]
.
.
.
$DATA

"fedSmokeHdr Test TC6"
"TC6/CIC"
Time Fed_Smoke_Md ANA_spd ANA_spd_ER ENG_TORQ opac_R fpmp_inT
Sec none rpm rpm LB_FT %_OPAC deg_F
$
0.000 0 691 8.9 188 1.65 105.0 ...
0.047 0 704 -4.5 182 2.08 105.0 ...
0.097 0 690 9.7 190 2.06 105.0 ...
0.147 0 710 -10.2 188 1.94 105.0 ...
0.197 0 695 0.4 182 1.98 105.0 ...
0.247 0 698 2.3 190 1.84 105.0 ...
0.297 0 698 1.8 184 1.85 105.0 ...
0.347 0 707 -6.6 189 1.95 105.0 ...
0.397 0 691 9.3 177 1.88 105.0 ...
0.447 0 690 10.3 180 2.16 105.0 ...
0.497 0 709 -9.3 178 2.11 105.0 ...
0.547 0 698 1.9 175 1.78 105.0 ...
0.597 0 695 5.3 187 1.53 105.0 ...
0.647 0 692 8.2 180 1.81 105.0 ...
0.697 0 705 -4.9 189 2.09 105.0 ...
0.747 0 701 -1.3 187 1.92 105.0 ...
0.797 0 702 -1.3 179 1.66 105.0 ...
0.847 0 695 5.3 189 1.75 105.0 ...
0.897 0 710 -10.4 185 1.88 105.0 ...
0.947 0 692 8.0 190 1.79 105.0 ...
0.997 0 690 -6.7 189 2.03 105.0 ...
1.047 0 708 -7.5 187 1.90 105.0 ...
.
.
.

```

6 Analysis and Reporting

The data logged by the federal smoke cycle is analyzed and a set of reports is generated at the completion of the test cycle. The analysis consists of performing validity checks on the test cycle and sorting and processing the smoke data as required in the federal register. Three types of reports are generated: a smoke certification report on each individual cycle; a smoke development report on each individual cycle; and, a summary report which provides cross-cycle analysis results. Refer to *Section 2.1 Sample Output Reports* on page 3 for examples.

While the analysis and report generation process occurs automatically at the end of each test, the option is provided to start it manually with the `fedSmokeRep` command:

```
fedSmokeRep [options]
```

where options take the form of a three-character name, an equal sign, and a value string, e.g., `cyc=1`. Refer to cyflex.com for complete [fedSmokeRep](#) usage help.

Appendix A. General Usage Variable Specifications

```
#The following table is used to initialize the labels, units, and
#format
# strings of the rdata array in GENERAL_USAGE
#label      units      format  initial_value  interval
# Federal Smoke Parameters
th1         %          1       40             -
-
dy1         %          1       0              -
-
dy2         %          1       0              -
-
dy3         %          1       0              -
-
dy4         %          1       48             -
-
t1          sec        1       2              -
-
t2          sec        1       2              -
-
s1          rpm        1       50             -
-
s2          rpm        1       50             -
-
time_72     sec        1       -              -
-
```