The Federal Test Procedure (FTP) is used to verify that a particular powertrain meets strict federal new car emissions standards. It is performed on randomly selected "pre-production" sample vehicles under rigidly controlled test conditions.

The FTP uses an Inertia Weight Dynamometer and Constant Volume Sampling (CVS) system to measure the mass, in grams per mile, of HC, CO, CO2 and NOx emitted from the vehicle. In addition, this test is used to calculate the vehicle's fuel mileage performance.

FTP Transient Drive Cycle

The transient or driving portion of the test is performed in three phases and incorporates an on-road simulation of cold start-up, hot start-up, idle, acceleration, deceleration, and various part throttle speed/load conditions. The drive cycle is modelled after a typical Los Angeles commute during heavy traffic and is referred to as the Urban Dynamometer Driving Schedule (UDDS). The three phases of the driving test are as follows:

- **UDDS Phase 1**: Cold Start and Cold Transient
  - vehicle is cold soaked between 68°F and 86°F
  - vehicle is started and "driven" on dyno for the first 505 seconds of the drive cycle
  - constitutes 3.6 miles of the urban drive cycle
  - samples collected during this phase are stored in Bag #1
**UDDS Phase 2**: Cold Stabilized
- vehicle is driven for an additional 867 seconds
- constitutes 3.9 miles of the urban drive cycle
- samples collected during this phase are stored in Bag #2
- at the end of Phase 2, the vehicle is hot soaked for 10 minutes

**UDDS Phase 3**: Hot Start
- vehicle is driven for an additional 505 seconds
- repeats the 3.6 mile urban driving cycle from cold transient phase
- sample collected during this phase are stored in Bag #3

At the completion of Phase 3, the **SHED (Sealed Housing for Evaporative Determination) test** is performed by measuring the evaporative emission produced from the vehicle after being parked in a sealed housing for 1 hour.

**FTP Certification Standards**
The Federal exhaust emission standards for the FTP are very stringent. The following are FTP cut points for 1977 and 1996 model vehicles:

- **1977 FTP**: HC = 1.5 g/m, CO = 15.0 g/m, NOx = 2.0 g/m
- **1996 FTP**: HC = 0.25 g/m, CO = 3.4 g/m, NOx = 0.4 g/m

As you can easily see, the FTP standards for 1996 are at least 4 times "tighter" than those standards established for 1977, which shows that new car emissions output has dropped dramatically over the past 20 years.

**FTP Standards vs. IM240 Standards**
Next, compare the FTP standards above to IM240 standards for 1977 and 1996 model years:

- **1977 IM240**: HC = 7.5 g/m, CO = 90 g/m, NOx = 6.0 g/m
- **1996 IM240**: HC = 0.8 g/m, CO = 15.0 g/m, NOx = 2.0 g/m

Roughly speaking, the new IM240 cut points are at least 3 times greater than the FTP requirements for the car when it was new. This leniency accounts for the normal aging of the vehicle’s engine/drivetrain and emission componentry.
FTP Test Equipment

FTP test equipment includes a chassis dyno, constant volume sampler, sample storage bags, and extremely accurate emission analyzers.

The FTP transient test uses a Variable Inertia Weight Dynamometer that is capable of constantly changing the load applied to the drive wheels. This feature allows the dyno to simulate the actual "loaded" driving conditions the test vehicle would encounter out on the highway.

Emission levels are captured and sampled using a Constant Volume Sampler (CVS). The CVS equipment samples 100% of exhaust output coming from vehicle, rather than just a small portion of exhaust like with shop grade exhaust analyzers.
Constant Volume Sampling (CVS)

The CVS used in FTP testing captures 100% of the vehicle’s exhaust output; thereby allowing mass emissions output to be calculated.

Sophisticated and precise measuring equipment is used to test and calculate the exact grams per mile produced of HC, CO, CO2, and NOX. This highly accurate and precise collection of test equipment includes:

- **Non-Dispersive Infrared (NDIR) Analyzer** is used to detect CO and CO2 in the exhaust flow, it is similar to shop grade exhaust analyzers; however, it is much more accurate.

- **Flame Ionization Detector (FID)** is used to detect HC in the exhaust flow. It is much more expensive and accurate than the Infrared Analyzer typically used in shop grade HC analyzers.

- **Chemiluminescence Detector** is used to detect Nitric Oxides (NO) in the exhaust flow. Nitric Oxides (NO) constitutes approximately 98% of total NOx emissions produced by motor vehicles. This detection method is more accurate and much more expensive than the electrochemical detection method used in shop grade five gas analyzers.

**FTP Test Results**

By using the equipment above, all the factors needed to accurately calculate the grams per mile of detected gases are provided. The calculated factors include the volume of vehicle exhaust (from the CVS), the concentration of the four gases (from the emission analyzers), and the total distance the vehicle travelled (from the dynamometer). As you can see, the FTP test procedure and its measured results vary greatly from the concentration-based emission testing you may be familiar with.
Basic Inspection & Maintenance Programs

As required by the Clean Air Act Amendments of 1977, Basic I/M Programs are currently active in many metropolitan areas nationwide. They are used by State and local government to certify in-use vehicles and are usually required for vehicle registration. The goal of these Basic programs is to ensure that engine/emissions control systems are properly maintained and that emission related componentry have not been tampered with.

Basic I/M Programs
Established by CAAA '77, Basic I/M identified vehicles in need of engine/emission control maintenance and repair.

Basic I/M Tests

Basic I/M testing typically consists of:

- **Visual Inspection** of key emissions control subsystems and components. This may include a visual check of the PCV system, air management system, EGR system, catalytic converter, and fuel inlet restrictor.

  The visual inspection is intended to confirm that the subsystem or component "appears functional" and usually doesn't include a "functional test". In some state programs, however, certain emissions subsystems must be functionally tested. For instance, California requires a functional test of the EGR system to confirm that it is operational.

- **Non-Loaded Tailpipe Test** for HC and CO concentrations. CO2 is also measured to check for possible exhaust dilution (exhaust leak). The tailpipe test is typically a "two speed idle test" which requires that emission readings are taken at idle, then at 2500 rpm, and again at idle. For this, the lowest of two idle readings and 2500 rpm reading are used to determine the pass/fail status of a vehicle.
The exhaust analyzers used for this test measure **HC and CO concentration** in parts per million (ppm) and parts per hundred (percentage) respectively. NOx is not checked during this test since the engine cannot be "loaded" adequately to produce significant amounts of NOx.

Basic I/M certification standards are much "looser" than FTP standards. Because Basic I/M measures "exhaust concentration" and FTP measures "mass emissions", it is difficult, if not impossible, to compare the results of these tests against one another.

**Required Equipment and Certification**

Various grades of California Bureau of Automotive Repair (BAR) certified infrared exhaust analyzers are used in the Basic I/M Programs. BAR establishes equipment standards for exhaust analyzers used in the California "Smog Check" program. Typically, other States have adopted or modified equipment approved by BAR for their own I/M program. The most common equipment used in Basic I/M Programs are the BAR 84 and BAR 90.

Certification also helps to establish requirements for equipment accuracy, ability to prevent test results tampering, ability to prompt technician through diagnosis and test procedures, as well as the ability to store data on tested vehicles and communicate with mainframe computers.

**Shortcomings of Basic I/M Programs**

One of the objectives of I/M programs is to ensure that vehicle engine/emission systems continue to operate as designed as the car gets older. To ensure systems function as intended, vehicle emissions should not be significantly higher than the standards to which they were designed. In short, vehicles should be tested against the FTP standards for the model year it was certified.

The problem with the Basic Two Speed Idle test is its failure to consistently correlate with the FTP test. According to one study done by the EPA, approximately half of all the vehicles which pass a two speed idle test, would fail an FTP test. This equates to about 50% false errors or **errors of omission**.

The same study indicates that about one out of every 75 vehicles fails a two speed idle test, but would pass the FTP test. This equates to about 1.3% **errors of commission**.
EMISSION TESTING & ENHANCED I/M

Enhanced Inspection & Maintenance Programs

As a part of the Clean Air Act Amendments of 1990, the EPA is requiring Enhanced I/M in areas which have a serious, severe, or extreme problem in meeting clean air standards. The certification goal of Enhanced I/M is basically the same as with Basic I/M Programs, that is, to ensure that vehicles are properly maintained and that emissions systems have not been tampered with.

Introduction to IM240

As previously mentioned, the EPA’s suggested Enhanced I/M Program is called IM240. IM240 identifies the car’s “true” emission output level by determining the volume of emissions it produces. It also incorporates a functional test of the evaporative emissions system.

IM240 is composed of three distinct tests:

1. Transient, Mass Emission Tailpipe Test
2. Evaporative System Purge Flow Test
3. Evaporative System Pressure Test

The IM240 differs from traditional I/M tests in that the emissions are measured while the vehicle is driven on a dynamometer. A few states currently test vehicles on a dynamometer, but only operate the vehicle at one speed. With IM240, the vehicle is operated over a driving cycle that has many different speeds, and includes vehicle acceleration and deceleration in a manner similar to city driving. Acceleration and deceleration can be significant sources of emissions from malfunctioning vehicles.

![IM240 Transient Drive Cycle](image)
IM240 Transient Test

The IM240 transient test is essentially a shortened version of the first 350 seconds of the FTP UDDS (Urban Dynamometer Driving Schedule) that is compressed to fit into a 240 second drive cycle. IM240 also includes the same test elements except the cold start test phase. Also, it is designed to have a close correlation with FTP while allowing for high throughput at centralized I/M test lanes. Hydrocarbon (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NOx) emissions are tested during the IM240 drive cycle. Remember, only HC and CO emissions are tested in most traditional I/M tests.

Drawbacks of Concentration Based Sampling

Shop analyzers that measure exhaust gas concentrations cannot measure the total volume of emissions emitted from the tailpipe.

Another important difference between IM240 and traditional I/M tests is that the IM240 captures the entire exhaust stream during the test and measures the total mass of emissions from the vehicle (that is grams of pollutant per mile driven) as opposed to the concentration of emissions in the tailpipe (% or ppm). Mass emissions are a more accurate way of measuring the emission performance of large and small engines, and are more directly related to the contribution that each car makes to air pollution. The IM240 is also capable of measuring fuel economy. If you recall, this is the same as the test procedures used for the FTP.

IM240 Evaporative System Purge and Pressure Test

The purge and pressure tests check for proper functioning of the evaporative emission system on the vehicle. The evaporative emission system is used to prevent fuel vapors from escaping into the atmosphere. In fact, evaporative HC emissions from motor vehicles actually exceed exhaust HC emissions, making them a vital aspect of Enhanced I/M Programs.

The evaporative emission system uses engine vacuum to draw fuel vapors temporarily stored in the evaporative canister, into the engine for combustion. The purge test determines whether this system is functioning properly by measuring the flow of vapors into the engine during the IM240. The pressure test checks the evaporative emission system for leaks that would allow fuel vapors to escape into the atmosphere.
The IM240 begins by driving the vehicle onto the dynamometer, activating vehicle restraints, positioning the exhaust collection device, and positioning the auxiliary engine cooling fan. An inspector then conducts the test by driving the vehicle according to a prescribed cycle displayed on a video screen. The inspector follows the driving cycle by using the accelerator pedal and the brake to speed-up and slow-down the vehicle in the same manner as if the vehicle were being driven on a city street. The vehicle speed is indicated by a cursor on the video screen, and the inspector adjusts the vehicle speed to keep the cursor on the driving cycle trace. This technique is easily and quickly learned by anyone who can drive a car.

The length of the IM240 test can vary depending on the emissions levels from the vehicle. The emission standards are about two to three times higher than the new car standards used to certify the vehicle. To determine emission levels, second-by-second instantaneous emission measurements are taken and integrated by a computer. The computer continually monitors the vehicle's emission levels during each phase of the test and uses fast pass/fail algorithms to identity exceptionally clean or dirty vehicles. As soon as the emission rates indicate that a vehicle is exceptionally clean or dirty, the computer automatically notifies the inspector to stop emission testing. For vehicles that are close to maximum allowable emission levels, the test may continue for a full 240 seconds. Thus, while the complete driving cycle is 240 seconds long (4 minutes), the average test time per vehicle should only be two to three minutes.

The IM240 transient test can be broken down into two phases that incorporates an on-road simulation of hot start-up, idle, acceleration, deceleration, and a several part throttle speed/load conditions. Details of the phases are as follows:

- **IM240 Phase 1:**
  - comprises the first 93 seconds of the drive cycle
  - samples collected during this phase are stored in Bag #1

- **IM240 Phase 2:**
  - comprises the remaining 147 seconds of the drive cycle
  - sample collected during this phase are stored in Bag #2

If the test requires the entire 240 second duration, the vehicle will have covered approximately 1.95 miles. As you can see, the certification standards for IM240 are very stringent; the 1994 certification standards are as follows:

- **HC = 0.8 g/m, CO = 15 g/m, NOx = 2 g/m**

Keep in mind, these standards are about 3 times “looser” than the FTP standards that were used to test the same model vehicle when it was new. This allows for some tolerance from new car standards as a result of vehicle age. Additionally, when IM240 is compared to traditional I/M programs, the test results are much more indicative of emission levels that would result from "real world" driving conditions (loaded conditions, acceleration, deceleration, etc.)
IM240 Test Equipment

IM240 test equipment is similar to FTP test equipment. It includes a variable inertia dyno, CVS and highly accurate emission analyzers.

IM240 Transient Test Equipment

The equipment needed for IM240 is essentially the same as that used for FTP; however, it differs greatly from the equipment used to perform either an idle test, which is used in most currently operating I/M programs, or the single-speed dynamometer tests used by some I/M programs. These differences include dynamometer capabilities, video driver trace monitors, special sampling systems, and emission analyzers. In addition, the high-tech test system will use computer controls with integrated quality assurance functions and will be completely automated.

The following test equipment is used in IM240:

- Variable Inertia Weight Dynamometer
- Constant Volume Sampler (CVS)
- Sophisticated Emission Measurement Equipment:
  - Non-Dispersive Infrared (NDIR) for CO and CO2
  - Flame Ionization Detector (FID) for HC
  - Chemiluminescence detection for NOx

The primary difference between the Variable Inertia Weight Dynamometer used for the IM240 and those used for single speed I/M tests is the addition of inertia flywheels. The inertia flywheels selected are based on the weight of the car being tested, and allows the inspection test to simulate vehicle inertia during acceleration and deceleration. This allows the emissions of the vehicle operating under these normal driving conditions to be measured. This type of dynamometer is widely available and is similar to the ones used by EPA and car manufacturers for new car certification.
The selection of the inertia weight and test horsepower for an individual vehicle will be automatically determined by computer so that the I/M inspector is only required to drive the vehicle onto the dynamometer. Even the system used to hold the vehicle on the dynamometer will be automatic in order to minimize test setup and improve testing throughput.

The mass of emissions emitted by a vehicle are determined by collecting the entire exhaust flow from the vehicle with a device known as a **Constant Volume Sampler (CVS)**. Within the CVS, the exhaust is diluted by fresh air, and the total volume of the exhaust mixture is measured. Combining the total volume measurement with the concentration levels of pollutants in the mixture (i.e., % or ppm) allows the total mass of emissions to be calculated.

The fresh air dilution is vital because it ensures capture of the entire exhaust sample and it protects the emission analyzers from high concentrations of water vapor produced by the vehicle. The dilution process also allows the measurement system to accommodate the difference in exhaust flow between small engines and large engines while measuring the true amount of emission from each type of engine.

The diluted sample, however, lowers the concentration of the pollutants to be measured, and hence, requires more sensitive emission analyzers than those used by traditional I/M programs. In addition, the method for measuring HC emission uses a different technique than traditional programs. HC emissions are measured with a **Flame Ionization Detector (FID)**, while CO and carbon dioxide emissions are measured using **Non-Dispersive Infrared Analyzers**. NOx emissions are measured with a **Chemiluminescence analyzer**.
Sample IM240 Transient Test Results

The IM240 drive trace is superimposed over graphs representing output levels for tested gases. These readings can then be analyzed against various IM240 operating conditions (acceleration, deceleration, cruise, etc.).
Evaporative System Purge Test

Since 1971, fuel tanks on cars have been designed to be a closed system in which vapors that evaporate from the gasoline in the tank are not released into the atmosphere. The system is sealed and under pressure so that excess vapors are shunted to a charcoal canister; also known as the evaporative canister.

The evaporative system purge test is used to determine whether fuel vapor stored in the evaporative canister are being properly drawn into the engine for combustion while the car is being driven. If the purge system is not working properly, then the evaporative canister can become saturated with fuel vapor and start to leak hydrocarbons into the atmosphere.

The purge test is conducted while the vehicle is driven on the dynamometer. Purge flow is measured by simply inserting a flow transducer in-line with the canister purge hose.

Purge failures are determined based on the total flow observed during the IM240 transient test, not by instantaneous flow rates. The vehicle must have a minimum of 1 liter of flow in order to pass. Most cars in proper working order will accumulate as much as 25 liters or more during the IM240 transient cycle. As soon as a vehicle exceeds 1 liter of flow the purge test is complete. For this reason, the purge test time is usually very short for most vehicles.

The purge test requires a flow meter that can measure the total vapor flow over the transient cycle. Hoses and universal fittings are used to hook up the flow meter as shown below and a computer is used to control the test process, collect and record test data.
The pressure test checks the tank vent system for leaks that would allow fuel vapors to escape into the atmosphere. A "pressure decay" method is used to monitor for pressure losses in the system. In this pressurized method, the vapor lines to the fuel tank, and the fuel tank itself are filled with nitrogen to 14 inches of water (about 0.5 psi). To pressurize these components, the inspector must locate the evaporative canister, remove the vapor line from the fuel tank and hook up the pressure test equipment to the vapor line. After the system is filled, the pressure supply system is closed off, and the loss in pressure is measured. If the system remains above 8 inches of water after two minutes, the vehicle passes the test.

A source of nitrogen, a pressure gauge, a valve, and associated hoses and fittings are needed to perform the pressure test. In addition, a computer is used to automatically meter the nitrogen, monitor the pressure, and collect and process the results. In addition, algorithms are used to optimize the test so that a pass/fail decision can be made in less than two minutes.

At this point, you should now have a thorough understanding of the evolution and theory behind Basic and Enhanced I/M programs. It is important to note that emissions failures will not necessarily cause a resulting drive-ability symptom, nor will driveability concerns always result in emissions failure. However, many times these problems may be related and may lead to the same system component failure. In any case, whether it’s a drive-ability symptom or an emission system failure, you would troubleshoot each in the same manner.