EVEREST KANTO CYLINDER LTD

Safety Instructions for Handling and Inspection Manual for Type 1 On-Board CNG Cylinders

Table of Contents

1.0 Compressed natural Gas (CNG)
2.0 Why CNG
3.0 Compressed Natural Gas (CNG) Cylinders for Natural Gas Vehicles
4.0 Terms and Definitions
5.0 Sensitivity of cylinder materials to operating conditions and solutions

Installation
6.0 Cylinder Mounting
7.0 Cylinder Shielding
8.0 Cylinder handling
9.0 Cylinder Defueling
10.0 Atmospheric Venting Equipment
11.0 Emergency defueling procedure to atmosphere
12.0 Scheduled defueling procedure

Inspection
13.0 Cylinder Inspection
14.0 Guidelines for Visual inspection
15.0 General Visual inspection
16.0 Detailed Visual Inspection
17.0 Classification of Visual Damage
18.0 Cylinder Destruction
19.0 Hydrostatic testing
20.0 Acoustic Emission Testing

Damage
21.0 Types of Cylinder Damage
22.0 Surface corrosion in steel cylinders
23.0 Fatigue cracks
24.0 Impact Damage
25.0 Stress Corrosion
26.0 Fire and Heat Damage

27.0 Protection and inspection of PRD and cylinder valves
28.0 Handling and Storage of Cylinders.

1. Compressed Natural Gas (CNG)

CNG is a natural gas which is a mixture of different gases mainly Methane (90-92%). It is available in many countries under the earth in abundance. It is called as Green Fuel due to its low emissions when used in Internal Combustion S.I. Engines. CNG is much safer than other fossil fuels in the event of a spill (natural gas is lighter than air, and disperses quickly when released).

CNG is made by compressing natural gas (which is mainly composed of methane [CH_4]), to less than 1% of its volume at standard atmospheric pressure. It is stored and distributed in hard containers, at a normal pressure of 200–220 bar (2900–3200 psi), usually in cylindrical or spherical shapes.

2. Why CNG

Salient features of CNG are known world-wide by all automobile manufacturers and users.

The major threats to urban air quality are heavy duty diesel vehicles. Switching over from Diesel to CNG in HMV will be more beneficial to the air quality and noise reduction (due to changed engine combustion) as well, where diesel powered HMV generally are considered to be a big nuisance.

CNG is now being used in traditional gasoline internal combustion engines that have been converted into bi-fuel vehicles (Gasoline/CNG). Natural gas vehicles are increasingly used in Asia, Europe and South America due to rising gasoline prices.

In response to high fuel prices and environmental concerns, CNG is now being used also in light-duty passenger vehicles and pickup trucks, medium-duty delivery trucks, transit and school buses, and trains.

Techno-commercial advantages of CNG as auto-fuel

Clean burning fuel:-It is clean, high octane eco-friendly, non-conventional and most suitable fuel for automobiles. Having anti knock properties due to its fuel characteristics reduce carbon deposition inside the engine which helps in good cooling because the carbon patches do not conduct heat as much as the metal of the engines. CNG as and alternative gaseous automotive fuel is useful for the city transport, delivery trucks, municipality trucks, and many other utility vehicles including Saloon Cars, Three wheelers, Auto Rikshaws and Two wheel motorcycles in cities.
Less pollution: - CNG reduces pollution because it is completely burnt out during combustion in the engine and hence emits much less pollutants compared to other fossil fuels like petrol or diesel
Engine life:-CNG gives increased engine life.
Pure and full:-In case of CNG there is neither adulteration possibility nor pilferage.
Energy consumption:-1.39 Ltr of diesel is equal to 1kg of CNG and 1.95 Ltr of Gasoline
Engine specifications: - After conversion the specs do not change and Borex Stroke remains the same

3. Compressed Natural Gas (CNG) Cylinders for Natural Gas Vehicles

CNG cylinders are made to contain compressed high-pressure natural gas. The high pressure gas exerts great amount of forces on the walls of the cylinders. To withstand these forces, cylinders are made of thick-walled, high strength materials such as Steel, Aluminum or composites.

The most widely used NGV cylinders are made of steel and have a long history of NGV service

Picture of Type 1 CNG Cylinders

Cut Section of type 1 CNG Cylinder

Cut Section of Type 1 CNG Cylinder Neck

Cut section of type 1 CNG Cylinder bottom

70 to 80 % of all the cylinders used in NGV service today are made of Seamless steel (Type 1). Type 1 CNG cylinders are re-known for their established safety performance, material and design characteristics. They are produced using seamless tubes, billet piercing and plates. Every process has its own pros and cons.

The most widely used manufacturing process is hot spinning of seamless tubes. Wall Thickness is designed through the relevant guidelines of various manufacturing standards.

The standards are country specific and differ from country to country. The most widely used standards are ISO 11439, ISO 9809, EN: 1964, NZS: 5454, ECR 110, IRAM (On-Board) and other NGV standards.

Approval Process

As per the relevant standard agreed between the customer and the manufacturer a technical file is prepared for approval by relevant inspection agency. The technical file consists all the relevant design parameters, manufacturing process, material composition, QAP, detailed dimensions and other specifications like Threading details, Working Pressure, Test Pressure.

4. Terms and Definitions

All metal Cylinder	:	A cylinder that is made from metal only
Acoustic emission	:	A form of non-destructive cylinder inspection
Composite Cylinder	:	A cylinder made entirely from non-metallic Materials such as plastic and composites
Aluminum	:	A material used to make cylinders
Carbon fiber	:	Type of fiber used to wrap composite cylinders
Composite	:	----------
CNG	:	Compressed Natural gas Stored at high pressures
Condemned Cylinder	:	A cylinder that must be removed from service. The cylinder is considered condemned when it damaged beyond repair
Corrosion	:	Process that refers to oxidation of materials primarily in wet environments.
Cylinder	:	The thick walled pressure vessel used to store Compressed natural gas.
Cylinder Standard	:	Document used to guide the design, construction and use of cylinders.
Defueling	:	The process of removal of CNG from the cylinders
Destroyed	:	The process of cutting the cylinder into two or Drilling a hole complete through the cylinder to Make it unusable.
Domes	:	the curved portion of the cylinders
Fatigue	:	Cylinder damage that occurs by repeated filling and Expending the fuel (Pressure Cycle).
Fuel Storage system	:	Cylinders used to store CNG on NGVs. A NGV can One or more cylinders to store CNG.
Fuel Delivery System	:	The system that delivers fuel to the engine, Includes tubing, valves, regulators, filters.
Galvanic Corrosion	:	Corrosion that occurs when different materials come into contact.
Hoop – Wrap	:	The wrapping used to wound the cylinder, only the Side walls are wrapped leaving the domes.
Hoop wrapped Cylinder	:	A cylinder that used hoop-wrap for reinforcement
Hydrostatic test	:	A test performed on a cylinder when the cylinder is Pressurized hydraulically to at least 1.5 times the Service pressure and the cylinder volumetric Expansion is used to determine its condition.
Impact Damage	:	The damage caused by dropping the cylinder or by A blow from another object.

Level 1 Damage	:	Minor damage that is considered normal and Should have no adverse effect on the safety of the Cylinder and its continued use.
Level 2 Damage	:	Moderate damage that requires the cylinder to be Repaired and re-qualified before returning to Service.
Level 3 Damage	:	Severe damage which is not repairable. The Cylinder is unfit for continued service and must be Condemned.
Liner	:	An internal component of cylinder made from Metal and plastic which provides structural support
Manufacturer's Label	:	The label containing the official markings as Required by the cylinder standard.
Mounting Brackets	:	A device used to secure the cylinder to the Vehicle.
Natural Gas Vehicle	:	Vehicles that use natural gas as fuel
Pitting	:	Type of localized corrosion damage that occurs in Metal cylinders
Ports	:	The opening at the end of the cylinder in which Valves, pressure relief devices and plugs are Installed
Pressure Relief Device (PRD)	:	A device integrated with cylinder valve which will release the gas in an emergency, such as fire.
Rejected Cylinder	:	A cylinder that must be removed from service and Evaluated further before final inspection.
Road Debris	:	Material such as small rocks, stones that have the Potential to cause damage to the cylinders.
Service Life	:	The service life of the cylinder as indicated by the Manufacturer's label.
Service Pressure	:	The service pressure is the pressure at a uniform Gas temperature of 70o F and full gas content. This is the nominal cylinder pressure rating.
Shielding	:	Structure constructed and installed on a vehicle to Protect and shield the cylinder from road debris Or any other external object.
Side wall	:	The cylindrical portion of the cylinder
Solid Plug	:	A threaded plug used to protect the cylinder port
Steel	:	Material used to make cylinders and liners
Stress Corrosion Cracking	:	A form of cracking that occurs as a result of combination of stress and a corrosive environment
Type 1	:	Classification for cylinder that is constructed solely from metal. Also known as all metal cylinder.
Type 2	:	Classification for cylinder that is constructed using A metal liner and a composite hoop-wrap. Also

		Known as hoop-wrapped cylinder.
Type 3	:	Classification for cylinder that is constructed from a Metal line and a composite full wrap. Also known as fully wrapped cylinder
Type 4	:	Classification for cylinder that in constructed from A plastic line and a composite full wrap. Also Known as an all-composite cylinder.
Thermal Trigger	:	the portion a of thermally activated pressure relief Device that is activated by excessive heat.
Valve, manual	:	A device installed on a cylinder to control flow of Gas to and from the cylinder. The device is Operated Manually with a knob.
Valve, solenoid	:	A device installed on a cylinder to control flow of Gas to and from the cylinder. The device is tuned on and off electronically.
Visual Inspection	:	A form of inspection where a trained inspector Examines a cylinder for signs of damage
Vent Line	:	A high pressure line from a pressure relief device To a location outside the vehicle

5. Sensitivity of cylinder materials to operating conditions and solutions

Summary of Sensitivity of Cylinder Materials.

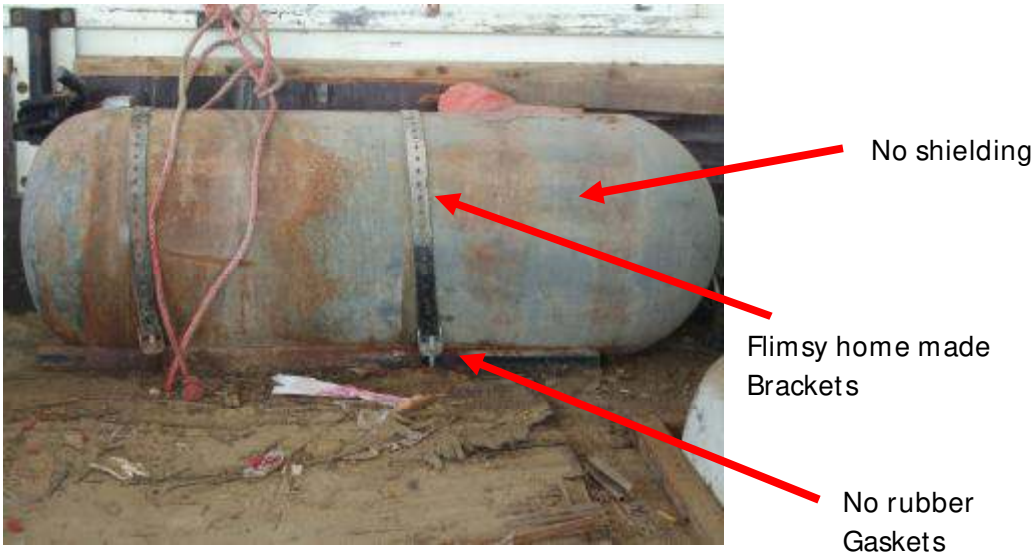
Material	Possible Damage	Solution
Steel	May experience Corrosion of exposed Surfaces	Ensure steel is painted And cylinder is not in direct contact with other metals.
	Impact Damage	Ensure Cylinders are protected from road Debris And other external Objects. Use Cylinder Shields.
	Fire / Heat damage	Ensure Cylinders are not installed near the vehicle exhaust pipe. Perform periodic visual inspection.
	Weathering	Cylinder surface may get affected by ultraviolet radiation if exposed to direct sunlight. Use periodic Inspection of external coating.
	Chemical Attack	Avoid exposure to harsh chemicals, automotive fluids and battery acids. Do periodic inspection, check for pitting, discoloration of cylinder surface, signs of oxidation in case due to prolonged exposure
	Abrasion	Abrasion may occur due to continuous rubbing of cylinder with the road surface or some other material in an event of an accident or insufficient ground clearance. Ensure proper clearance when vehicle is loaded to gross weight limit.

6. Cylinder Mounting

Proper care should be taken when mounting cylinders

- The cylinder support mechanism should be strong enough to withstand force equal to 8 times the cylinder weight.
- Should allow liquids to drain, accumulation of liquids like water can lead to rusting.
- Mounting should be done in such a way that cylinder markings are easily accessible and can be read without much effort.
- Prevent abrading, minimize and withstand vibrations.

A Typical poor installation and mounting problems are illustrated follows:



Example of a poor Cylinder Installation.

7. Cylinder Shielding.

Cylinder Shielding should be used to protect the cylinder.

- Damage from road Debris
- Damage from Vehicle cargo
- Weather elements
- Exhaust Heat
- Harmful Liquids
- Excessive sunlight
- From each other, if more than one cylinder is installed.

Shielding is primarily used for cylinders that contain composite materials. But it is a good practice to use shielding for Type 1 cylinders especially in cases of underbody installations.

8. Cylinder handling

It is not recommended / advised to remove cylinders from the vehicles except in the following emergency scenarios

- If vehicle has been involved in an accident or fire
- Vehicle maintenance requires cylinders to be removed
- Cylinder inspection or re-testing is required
- Irreparable damage to the cylinder and the affected cylinder is condemned.

If the cylinder is to be removed, the following precautions have to be taken. Only authorized trained personnel should be allowed to handle the cylinders

- Cylinders should not be dropped
- Cylinders should not be dragged
- Cylinders should not be lifted by using the attached valves / PRD as leverage or support.
- Cylinders should not be rolled off storage.

9. Cylinder Defueling

In two cases cylinders must be defueled (Depressurized)

a. Emergency defueling
b. Scheduled defueling

Emergency defueling must be performed when vehicle is involved in an accident /collision or fire at there is a need to remove CNG from the cylinder to prevent immediate hazard to people or immediate surrounding.

A scheduled defueling is planned removal of CNG from the cylinder which may be required in the following events.

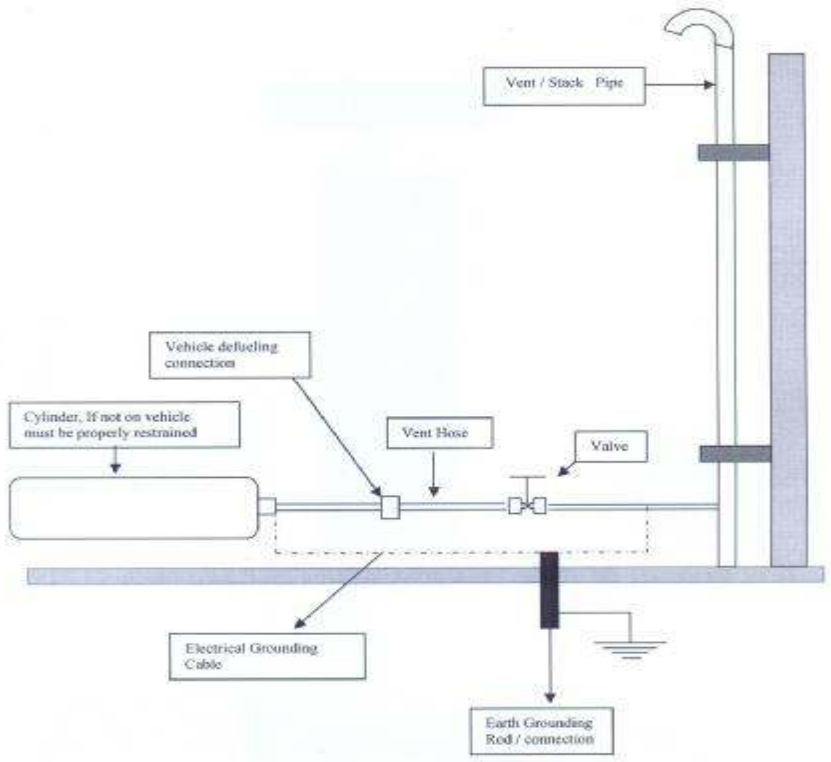
- Testing
- To return the cylinder to the manufacturer
- To carry certain maintenance work as per manufactures' guidelines.
- When cylinder is to be condemned.

Cylinder defueling is not required for routine visual inspection. In cases where defueling becomes absolute necessity the local authorities should be consulted for guidance and recommendations. Vehicle manufacturer's instructions should also be reviewed for proper venting procedure. Use of proper tools and steps are of outmost importance. Special care should be given to electrical grounding to prevent gas ignition because of static electricity buildup.

10. Atmospheric Venting Equipment.

The use of atmospheric venting of natural gas to depressurize a CNG cylinder must be done with extreme care. Improper equipment or procedure increases the risk of gas ignition from nearby ignition sources such nearby flames, static discharge etc,.

A static electrical discharge can build up when venting gas. This electric charge can ignite natural gas.



General Atmospheric Venting Equipment

A schematic diagram of a typical venting system is shown above.

The system will also include the following equipment.

- On-Board defueling connection installed on the vehicle
- Vent pipe. The pipe typically should be 2-inch in diameter and should be properly supported by a fix structure such as a wall. The pipe should extend a minimum of 2 feet in height than the support structure. The pipe must be electrically grounded and no ignition source should be near the system.
- Electrical ground connection consisting of a minimum 2 gauge or heavier copper wire attached at one end to a rod or another suitable electrical ground. The other end should be clamped to the venting pipe and the cylinder valve.
- A high pressure flexible hose
- A manual valve to control the gas flow.

In addition to the above items, it is recommended to keep the following safety equipment lose by

- A portable fire extinguisher
- Paste NO-Smoking and "Flammable Gas" signs near the designated area.

If the cylinder is not mounted on a vehicle it should be properly restrained as it may move if the gas is released at a fast rate.

11. Emergency Defueling Procedure to Atmosphere

Emergency venting procedures should be used in situations where there is an absolute need to remove CNG form the cylinder immediately and it is not possible to follow the normal recommend defueling procedure

The general procedure for emergency defueling is as follows:

- Ensure that an emergency electrical connection has been established between the cylinder, the vent system and earth ground.
- Connect the on-board defueling connection to the vent system suing a high pressure flexible hose.
- Open the hand valve to release the gas. Adjust the manual vale to have a steady flow of gas. Transfer the gas at a slow rate to prevent freezing. If electronic solenoid valves are used then consult vehicle manufacturer for information.
- Allow the on-board storage system to vent completely.
- Disconnect all the connections once the venting is complete.

12. Scheduled Defueling Procedure.

Scheduled defueling is the preferred method of depressurizing cylinders. In this process two steps are involved.

Step1.

Run the vehicle to reduce pressure. Move the vehicle to an outdoor Location and run the vehicle to use as much CNG as possible.

Step2.

Residual gas removal. This can be done by safely venting the gas to the Atmosphere.

Step 1 will not vent the gas completely. The residual gas must be vented to atmosphere using the atmospheric venting procedure.

13. Cylinder Inspection.

All cylinders are designed with high safety factors and undergo stringent quality tests in all stages of the manufacturing process. The cylinders need to be periodically examined / retested every few years* to ensure safety all through out their service life. Inspection determines their general condition and fitness for continued usage.

There are three types of inspections (See table below) which can per carried out to assess the cylinder's overall condition and fitness levels.

Inspection Type	Description	Removal of Cylinder From Vehicle	Frequency
Visual	Primary Inspection Method, recommended by all manufacturers	No	3 years or 36000 K.M (which ever is earlier)
Hydrostatic	Required by vehicle or cylinder manufacturers. Should be done as per the guidelines of local regulatory authority.	Yes	5 years for Type 1 Metal cylinders.
Acoustic Emission	Non Destructive test that may be done in conjunction to supplement visual inspection.	No	May be performed along with visual inspection

* The Duration of Periodical Inspection/ Re-testing is defined by the regulatory authority of each country.

NGV Standards and ISO 11439 define the periodic inspection of CNG cylinder every 3 years until the specified service like of the cylinder.

Many countries where the service life of the CNG Cylinder is undefined insist hydrostatic re-testing of cylinders every 5 years.

14. Guidelines for Visual inspection.

Visual inspection can be carried in two ways.

- Periodic General Inspection
- Periodic Detailed Visual inspection

Elements of Visual Inspection

Inspection Type	Description	Frequency
General Visual Inspection	Inspection performed by vehicle owners, fleet managers and technicians to check for any signs of damage to the cylinder.	During routine maintenance or as specified by the safety plan
Detailed Visual Inspection	Detailed inspection should be performed by trained technical staff as recommended by the manufacturing standard, local regulatory authority or from cylinder manufacturer.	3 years or 36000 K.M (which ever comes first)

Detailed visual inspection is must for NGV cylinders and should be carried out at recommended frequency.

Visual inspection should become an integral part of any fleet's operational manual and should be done by the technicians whenever the vehicle is brought in for regular preventive maintenance.

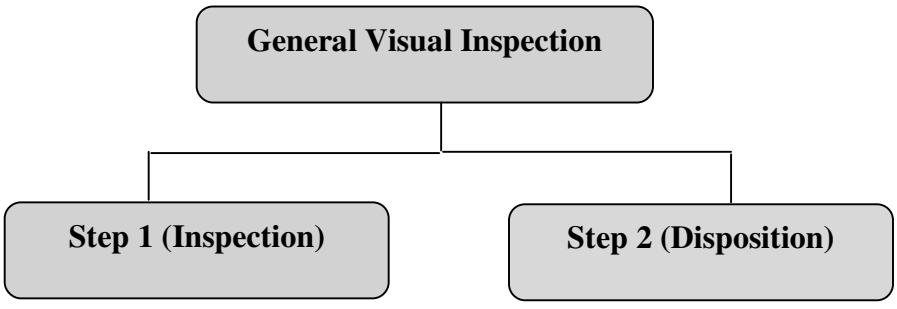
15. General Visual Inspection.

Summary:	General visual inspection of cylinder is done for signs of external damage Or abuse. These inspections should be done as a part of normal preventive maintenance or other regularly scheduled activity.
Performed by:	Owner / Operator
Removal of Cylinder:	No
Removal of shielding:	No (Optional)

Frequency: The following recommendations should be followed

- Performed during any vehicle maintenance
- Performed at monthly intervals by refueling or service personnel.

Methodology: The general visual inspection contains two steps as follows:



Step 1. Inspection

If the vehicle is not on a lift and cylinders are mounted underneath, use a creeper or jack to access cylinders

If cylinders are roof mounted open roof mounted shields

Examine each cylinder to ensure that each cylinder is securely attached to the vehicle

Examine each cylinder for signs of gross damage.

Note: If cylinders are shielded check shields for signs of damage. If shields are damaged, perform a detail visual inspection by removing the shield. If cylinder is damaged go in for re-qualification procedure.

Step 2. Disposition

If rubber gaskets / mounting straps are loose or not in place or there is rotation of cylinder straining the piping then loosen the mounting brackets, reposition the gaskets and re-torque bolts.

Check for damage to mounting brackets. If damaged, check if cylinder is damaged by [performing detailed visual inspection. If cylinder is not damaged, obtain new brackets and remount the cylinders.

If cylinder gas heat damage, then perform detailed visual inspection and classify damage as per section **********

If there is apparent impact damage to the cylinder, perform a detailed visual inspection and classify damage as per section **********

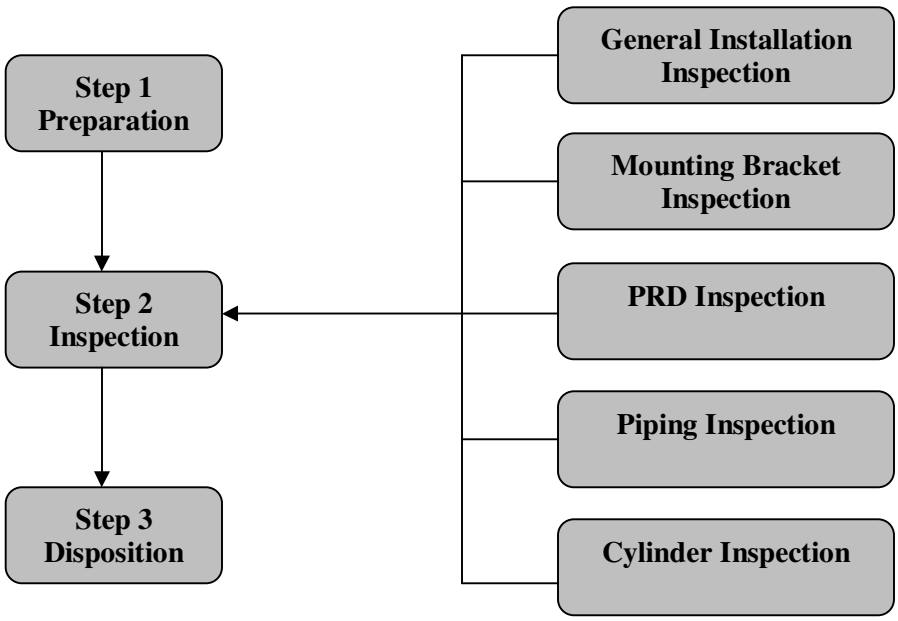
If there is abrasion damage perform a detailed visual inspection and classify damage according to **********

If there is damage to the PRD, perform a detailed visual inspection and classify damage according to ********

If there is damage to the valve, perform a detailed visual inspection and classify damage according to section **********

16. Detailed Visual Inspection

Summary:	The detailed visual inspection is a through visual inspection of the cylinder and bracket assembly by a qualified and trained technician.
Performed by:	Trained and experienced third party or trained in-house individual.
Removal if Cylinder:	No.
Removal of Shield:	Yes
Frequency:	Every 3 years or 36000 K.M (Which ever comes earlier)
Tools:	High intensity light, angled inspection mirrors, hand tools, torque wrench, depth gauge, ruler, leak test fluid,
Methodology:	The detailed visual inspection contains the following steps:



Step 1: Preparation

If cylinders are mounted underneath vehicle, lift the vehicle using a hydraulic lift

If cylinders are roof mounted, open roof mounted shields

If cylinders are mounted in the truck bed and are shielded, remove shields.

Clean cylinders with soap and water solution with a cloth

Note cylinder / vehicle details like serial number, date of manufacturing, vehicle number Etc

Step 2. Inspection: General Installation Guidelines

Verify that an appropriate label is on the cylinder and that the cylinder is being properly Used to store CNG only at the rated pressure

Verify that the cylinder service as defined by the manufacture life has not expired. If expired condemn cylinder

Ensure cylinders are protected from road debris and other forms of potential damage.

Step 2. Inspection: Mounting Bracket Inspection

Inspect each cylinder bracket for proper mounting to vehicle body. Check that fasteners or locknuts are tight and look for signs of cylinder movement

Verify that rubber gaskets are in place and are in good condition. Verify that the brackets are in good condition. Check bracket to vehicle mounting for signs of damage or stress (bent sheet metal or fractures)

Step 2: Inspection: PRD inspection

Verify that PRD is properly attached to the cylinder valve. If no PRD is present, contact valve manufacturer or their local sales agent.

Examine the valve and PRD assembly for damage. Damaged valve and PRD assemblies must be replaced outright. Inspect the PRD device for signs of bulging of the thermally active material. This can be performed by rubbing fingers over PRD at the thermal trigger.

Following are the general guidelines for PRD inspection. The inspector shall review the PRD manufacturer's recommendations to determine the actions for acceptance / replacement of the PRD

Type of Damage	Recommendations
Creeping of fusible material	PRD Should be replaced
Fatigue cracking of pressure burst Disk	PRD Should be replaced
Stress corrosion cracking of Brass Body	PRD Should be replaced
Freezing waterline damage	PRD Should be replaced

Note. 1. At the time of periodic visual inspection replace the PRD with a new one.

2. Components of PRD shall be reassembled, reinstalled in accordance with the Recommendations of the valve manufacturer

Step 2: Inspection: Piping and Hose inspection

Inspect tubing for leaks (with soap and water solution), damage, wear and signs of deterioration or corrosion.

Inspect hoses for leaks, damage, wear, and signs of deterioration and corrosion. Ensure loses are rated for CNG use, marked with manufacturer's name or trademark and marked with rated pressure.

Step 2: Inspection: General Cylinder Inspection

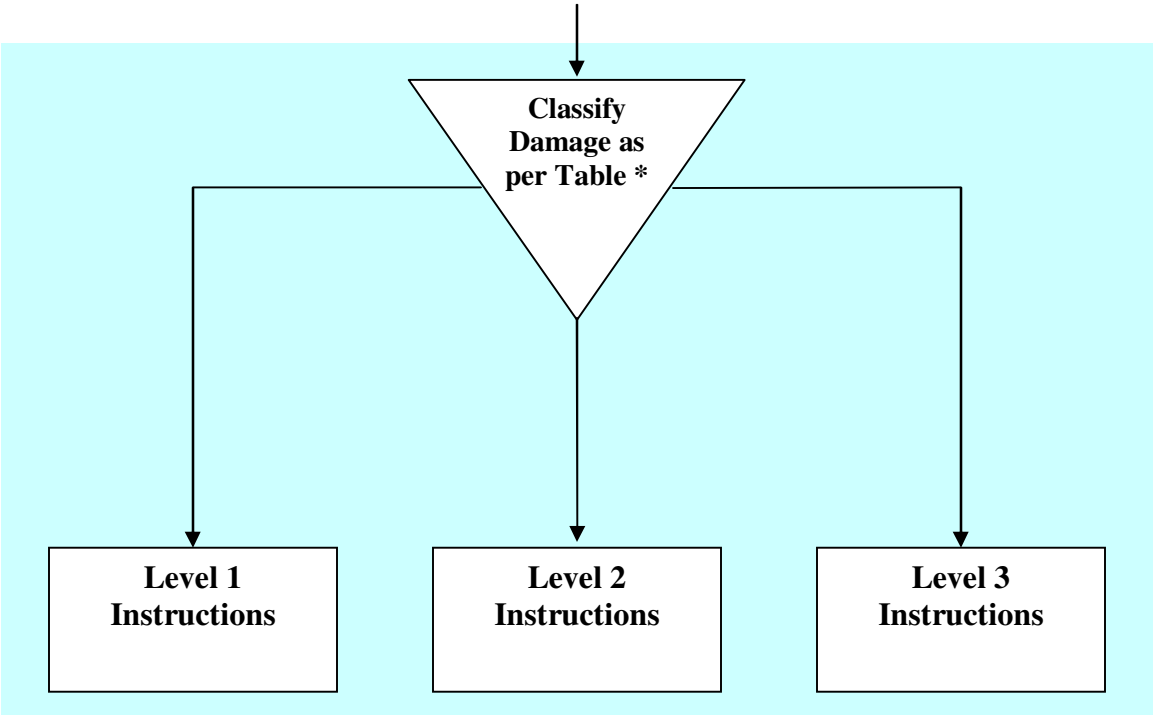
Perform detailed visual inspection starting at fill end and going to the opposite end. Use a flashlight, high intensity light and mirror to aid inspection.

If cuts, scratches or abrasions are visible measure the depth and length of the cuts and scratches using a depth gauge or calipers and rulers or ultrasonic thickness tester. Note the depth and length on the visual inspection data sheet.

Step 3: Disposition

After the visual inspection and damage areas should be classified. The following steps should be used to classify the damage:

Start



The following guidelines should be followed for disposition of cylinders

Level Of Damage	Disposition
Level 1	Cylinder approved for continued use
Level 2	The cylinder should be handled according to cylinder manufactures guidelines
Level 3	Cylinder must be condemned and destroyed.

At the completion of inspection, cylinders that are approved for continued use should have a sticker or notification placed on the cylinder or vehicle indicating the date and the identification of the inspector. Condemned cylinders should be marked and destroyed.

Levels Of Damage

The following Guidelines should be followed for disposition of cylinders. Refer the table below:

Level Of Damage	Disposition
Level 1	Damage is minor and less than 0.25 mm in depth. Such damage should have no adverse effects on the safety of the cylinder and its continued use. Damages such as scratched paint, nicks or dings that have no appreciable depth are considered to be in this category.
Level 2	Damage greater than or equal to 0.25mm in depth. Suck kind of damage is more serious than level 1 and should be given more attention. Such kind of damage can be repaired and the cylinder returned to service based on the recommendations given in table 3. All such cylinders should be properly repainted after carrying out the repair work before putting into re-service.
Level 3	All cylinders which are beyond repair as recommended in table 3 shall be rejected and condemned. Under any circumstances cylinders whose minimum wall thickness is less than the specified minimum design wall thickness shall be returned to service.

17. Classification of Visual Damage.

Type of Damage	Repair – Recommendations / Solutions
Cut / Scratches / gouges	A cut or scratch may occur on a metal cylinder when it is hit by a shard edged object. It is a sharp impression on the cylinder wall where the material is removed. If cut, scratches, gouges are in the range of 0.25 mm to 0.5 mm, repair it by rounding off the sharp edges by using hand operated power tool. Great care should be taken to avoid introducing new defects to the affected area. After such a repair job the cylinder should be re-examined to ensure that the wall thickness has not reduced below minimum specified wall thickness. The affected area should be repainted.
Abrasion.	Abrasion may be due to some metallic object continuously rubbing against the cylinder. It may be due to poor installation or bad road conditions. Metal cylinder showing evidence of abrasion shall be closely examined to verify the amount of metal removed. If the depth is greater than 0.5 mm and has reduced the wall thickness to less than the minimum design thickness then condemn the cylinder. If the thickness has not reduced below the specified minimum design wall thickness then prepare the surface for repainting. Use bonded abrasives mounted points of suitable shape and size for rounding off the edges. Use extreme care so as not to introduce new injurious defects.
Charring / Soot	If the cylinders are exposed to sunlight or if it is under any chemical effect, blackening or browning of the affected area may occur. Repaint the affected area.

Chemical Attack	When a cylinder is subjected or exposed to acidic chemicals its surface may get corroded or it may get dissolved. Metal cylinders exhibit pitting, corrosion and oxidation due to prolonged exposure to moisture, automotive fluids or corrosive agents. Under such cases wash off the chemicals thoroughly and examine the cylinder for evidence of chemical effect. Examine the cylinder for discoloration and material loss. If there is no effect, continue using the cylinder. For minor discoloration repaint the cylinder. If the cylinder suffers from pitting and corrosion examine the wall thickness. If it is still more than the minimum design thickness use appropriate abrasive paper to remove the corrosion marks and repaint the cylinder.
Dent	A depression may occur if the cylinder is hit by an object at high velocity. Minor dent of 0.5mm depth shall be rounded off by a manually operated power driven fine grit mounted wheel. This will reduce the stresses in the cylinder and improve safety. After such a repair cylinder should be re-examined to ensure that wall thickness is not reduced below the specified minimum design wall thickness. Prepare the surface and repaint the cylinder.
Weathering	Cylinder surface may get affected by ultraviolet radiation from sunlight. Degradation of external coating may lead to metal surface corrosion. The affected area may by cured by application of fresh coating.

General Corrosion, Pits, corrosion lines	It is an area of material loss due to chemical oxidation or rusting. Light corrosion can be cleaned and the affected area repainted. For heavy corrosion greater than 0.5 mm in depth the affected area should be reexamined to ensure that the wall thickness has not reduced below the specified minimum design wall thickness. If the wall thickness is more than the minimum design thickness Use appropriate abrasive paper to remove corrosion marks and repaint the cylinder. If the wall thickness has been reduced to less than the minimum design thickness condemn the cylinder

18. Cylinder Destruction

Cylinders that are condemned must be removed form service and destroyed in a safe manner. Cylinders should be destroyed in such a manner that they are rendered unusable and cannot be repaired in any way.

Before cylinders are condemned they should be checked for any residual gas. Even if the cylinders appear to be empty some small amount of gas will always be present. This gas must be completely removed and purged.

Refer section 10.0 to safely venting procedure. Cylinders should not be vented without proper electrical grounding.

The following steps / procedure should be followed:

1) Remove and purge the residual gas form the cylinder

2) Remove valves and other fittings (if any).

3) Erase the cylinder markings with a hand operated power tool. The markings should be rendered unreadable.

4) Drill a hole or cut the cylinder in half.

5) Scrap the cylinder.

19. Hydrostatic testing.

Hydrostatic testing is a test performed on high pressure gas cylinders to check for leaks or flaws and should be done every 5 years or at the frequency defined by the regulatory authority in the specific country.

Hydrostatic test involves filling the cylinder with a nearly incompressible liquid - usually water or oil - and examined for leaks or permanent changes in shape. Red or fluorescent dyes are usually added to the water to make leaks easier to see. The test pressure is always considerably more than the operating pressure to give a margin for safety, typically 150% of the design pressure. Water is commonly used because it is almost incompressible (compressible only by weight, not air pressure), so will only expand by a very small amount should the vessel split. If high pressure gas were used, then the gas would expand to perhaps several hundred times its compressed volume in an explosion, with the attendant risk of damage or injury.

Cylinders are normally tested using a water jacket test. The cylinder is visually examined for defects and then placed in a container filled with water, and in which the change in volume of the vessel can be measured by monitoring the water level. For best accuracy a digital scale is used to measure the smallest amounts of change. The vessel is then pressurized for a specified period usually 30 or more seconds and depressurized again. The water level in the jacket is then examined. The level will be greater if the cylinder being tested has been distorted by the pressure change and did not return to its original volume or some of the pressurized water inside has leaked out. In both cases, this will normally signify that the cylinder has failed the test.

After the test is carried out the information such as date of testing and the next test date is stamped on the cylinder. The cylinder serial number and other stamped data should be recorded and properly maintained for future testing and reference all through the cylinder service life.

20. Acoustic Emission Testing

Generally acoustic emission testing is not required for testing NGV cylinders. This test can be used to supplement visual inspection testing.

Acoustic emissions are stress waves that are generated by materials when they are stresses. Sensors mounted on the surface of the cylinder can pick up these stress waves. Damaged or degraded area of the cylinder emits more of these stress waves than an undamaged portion.

For inspection of CNG cylinders, the sensors are attached to the surface of the cylinder and the cylinder is refueled. Acoustic measurements are taken during this refueling. A damaged cylinder will emit more activity than an undamaged cylinder and the sensors will pick such emissions.

The major advantages of acoustic emission testing are:

1) It does not require removal of the cylinder form the vehicle.
2) This test can detect any internal damage in the cylinder.

The major drawback of the test is that it requires trained personnel to conduct and interpret the test results. The acoustic emission test also takes longer to conduct than a typical visual inspection.

Note. The acoustic emission test is not a substitute for a visual inspection test.

21. Types of Cylinder Damage

This section is to provide the user with a detailed description of types of damages that can be inflicted to a CNG Cylinder and the steps that are to be taken as per the type of damage incurred. This section also includes ways to prevent such types of damage from occurring.

Types of Cylinder Damage

Type of Damage	Section
Surface corrosion	**22**
Fatigue Cracks	**23**
Impact Damage	**24**
Stress Corrosion	**25**
Fire or heat Damage	**26**

22. Surface corrosion

Surface corrosion on steel can produce rusting or pitting. This surface corrosion can reduce the cylinder wall thickness, which if left untreated could result in weakening of the cylinder or failure. A lack of rubber gaskets under brackets can cause acceleration of the corrosion. There fore rubber gaskets are a must and should always be used.

Solution: Always ensure cylinders are painted. Light corrosion can be cleaned and cylinders repainted. For heavy corrosion and pitting, the approximate depth of the pitting should be determined and the cylinder should be removed from service if the depth of the corrosion or pitting exceeds more the .5 mm and reduces the minimum design thickness.

23. Fatigue Cracks

Any type of metal container such as a high pressure CNG cylinder will suffer from Fatigue cracking if it is subjected to a large number of pressure cycles. This type of fatigue generally starts from the interior of the cylinder.

NGV cylinders are designed so that fatigue cracking should not occur during the expected service life of the cylinder. Cylinders should not be used beyond their service life. The expected service life duration of the cylinder is marked on the cylinder.

24. impact Damage

If impact damage is suspected, the cylinder should be carefully examined using the detailed visual inspection procedure. The area of greatest concern is the neck and bottom of the cylinder. Impact damage may also occur when cylinders are dropped during handling. Extreme care should be taken when cylinders are being moved.

Damage can also occur from road debris and for this reason undercarriage mounted cylinder should be properly shielded.

25. Stress Corrosion

Stress corrosion can occur when the cylinder comes in contact with a corrosive liquid. Acids such as battery acid are one of the most corrosive agents. Stress corrosion can also happen when cylinders come into contact with very strong bases. For this reason batteries should never be transported in the bed of pick-up truck or located near the cylinders.

26. Fire and Heat Damage.

Fire and heat damage can occur in all types of cylinders. If a vehicle has been involved in a fire, then the cylinders should be removed and condemned. A more common form of damage is heat damage when the cylinder is too close to a heat source such as an exhaust pipe. Even though steel cylinders are less susceptible to such damage still they should be installed at some distance form the vehicle exhaust system, especially in undercarriage installations.

A minimum distance of 8 inches should be always maintained. And cylinders that are close to a heat source should have heat shields.

27. Protection and inspection of PRD and cylinder valves

Pressure relief devices (PRD) are essential part of an NGV cylinder fuel storage system. The main job of a PRD is mainly to release the natural gas from the cylinder in the event of fire. The PRD in case of fire prevents the build-up of pressure within the cylinder which can lead to cylinder wall rupture and eventual failure of the cylinder.

Gas pressure significantly increases when a closed cylinder is heated as in case of fire.

There are three types of PRDs:

1) Thermally Activated: These devices are activated only by high temperatures. This type of device generally contains a fusible material that can melt at a certain temperature. When this occurs, the meting of the fusible material opens up a path for natural gas to release through a vent hole. Almost all PRDs in use today are of this type.

2) Series Combination: These devices are activated by high temperature and high Pressure. This design generally has a fusible material that Is backed by a pressure burst disk.

3) Parallel Combination: These devises are activated by either high temperature or High pressure. The design generally has two vent paths, One is protected by a fusible material and the other by a Pressure burst disk.

A PRD device can suffer form the following problems:

1) Creeping of the fusible material
2) Fatigue cracking of the pressure burst disk
3) Stress corrosion cracking of brass body of PRD
4) Freezing water in the vent line damaging the PRD.

PRD vent lines should have a cap to prevent water from filling the vent lines. Periodic visual inspection is needed to make sure this cap is in place and that water or other external debris has not filled the vent lines.

During routine visual inspection if creeping, bulging and hairline cracks are observed, the PRD should be immediately replaced. Always remember PRD cannot be repaired. Replacement is the only recommended course of action in such scenario.

Picture of a typical Pressure Relief Device

28. Handling and Storage of Cylinders.

Improper Handling and storage of High Pressure gas cylinders have been reported as immediate causes of numerous incidents resulting in injuries and property damage. Because of their potential to cause incidents / accidents, the following rules for handling cylinders must be adhered to:

- Never drag, slide, or drop cylinders.
- Do not lift or move cylinders using the cylinder valve as leverage
- Transport cylinders in an upright position using a cart designed for that purpose.
- If forklifts are used to lift cylinders, take extra precaution as the forks can inflict damage to the cylinders.
- If cylinders are stacked, make sure the stacks are stable, if not the cylinders may roll / fall and injure personnel
- Protect cylinders from contact with ground, ice, snow, water, salt, corrosion, and high temperatures.
- Always place cylinders in a location where they will not be subjected to mechanical or physical damage and excessive heat.
- It is good practice to wear safety shoes and gloves when moving cylinders

Improper Way of Storing Cylinders, A steel or wooden stopper should be used to prevent cylinders from rolling off storage

The proper packaging / storing of cylinders for extended periods.

Cylinders should not be handled by Valve / PRD

Loading and unloading of cylinders with a forklift.