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Standard Operating Procedure (SOP)

Converting LPG Cylinders to Oxygen

www.tce.co.in/tce-combating-covid/

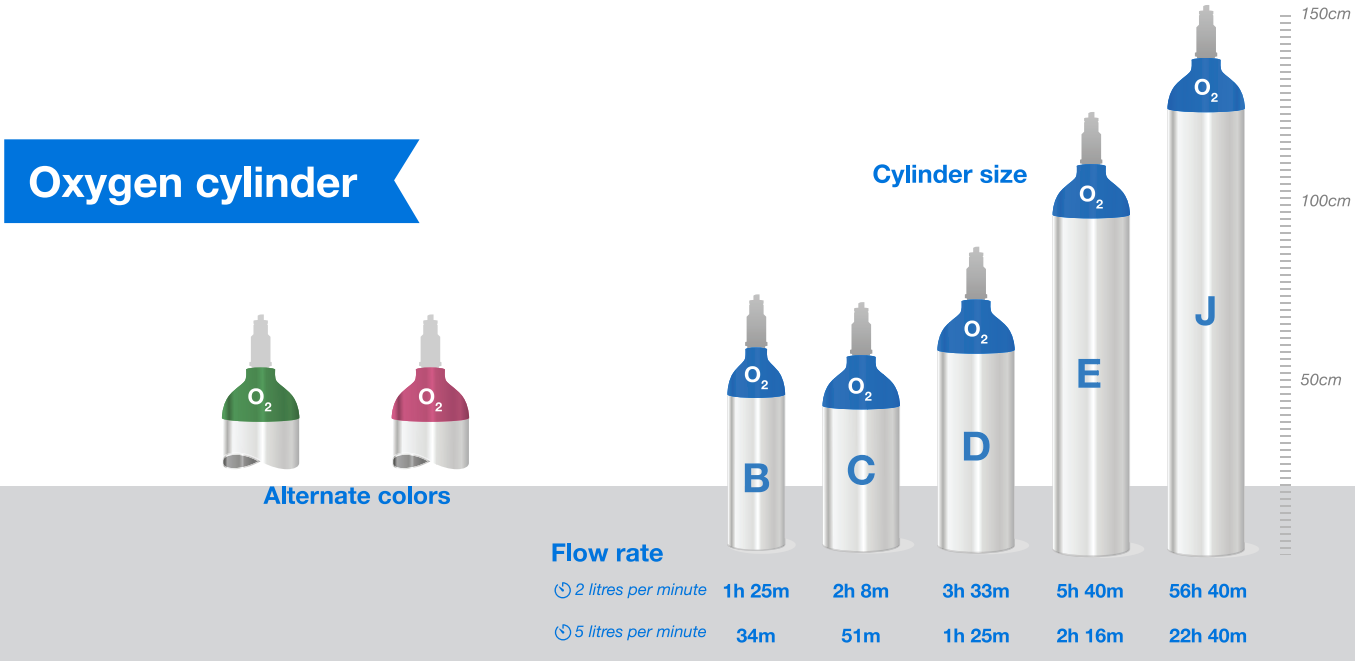
Executive Summary

India is almost at the end of the devastating second wave of COVID-19, which had spread across the country and claimed thousands of lives and affected millions. The country's medical infrastructure proved insufficient as many patients needed oxygen support and hospital beds for survival. The country witnessed a severe shortage of lifesaving medical oxygen in terms of production and distribution. To prepare for a similar oxygen emergency in future, especially for remote locations, LPG cylinders can be converted for Oxygen storage. This document suggests a Standard Operation Procedure (SOP) for this conversion.

Though the country's steel plants and oil refineries have quickly diverted industrial grade liquid oxygen from their plants to the regions with higher oxygen demand, the transportation, infrastructure for converting liquid oxygen to gas and filling in cylinders was not enough. The country also experienced a severe shortage of oxygen cylinders - the last mile connectivity between the oxygen generation facilities and patient beds. Various alternatives have been explored to store medical oxygen. One such alternative is domestic liquified petroleum gas (LPG) cylinder, particularly in rural India, to minimise dependency on the oxygen cylinders. (More details are available in whitepapers published at https://www.tce.co.in/tce-combating-covid/)

This document provides procedures that need to be followed whenever LPG cylinders are converted to store medical oxygen in emergencies. It is to be noted that this is the suggested procedure based on the standard practice followed in the industry and recommendations provided in "International standard- ISO 11621". This document also captures the findings reported by ISRO (Reference - ISRO Report on LPG Cylinder Testing – June 2021) during the testing of the LPG cylinder conversion process. This document thus compiles the information provided by ISRO in their report, ISO standard and other sound engineering practices in the industry. The objective is to devise the standard conversion procedure.

Implementation of this concept shall involve further Statutory, Legal and other approvals and must be done with the proper involvement of Government authorities. A governance mechanism involving government officials, PESO, Controller of Explosives, Fire Department, Medical Department (Min. of Health) and administrative authorities are also required for related compliances and approvals.



Stages of Conversion

The conversion of LPG cylinders to oxygen service involves external as well as internal inspection and cleaning. The overall conversion process can be classified under four significant stages, as depicted in Figure 1. These stages are further discussed in detail in sections that define stepwise Standard Operating Procedures (SOP).

The first stage is to inertise the cylinders. For this purpose, the LPG cylinders will be depressurised. The one-way flow regulator valve with NRV shall be replaced with a standard valve before the inertisation procedure is started. When the used LPG cylinders are to be converted, the inertisation will begin with a solvent cleaning process followed by nitrogen purge cycles. The last step during the inertisation process shall involve oxygen purge cycles and testing.

The second stage is to perform leak testing for ensuring that the converted cylinder is leak-proof, followed by External inspection and cleaning. The last step is implementing the colour coding and markings for oxygen service

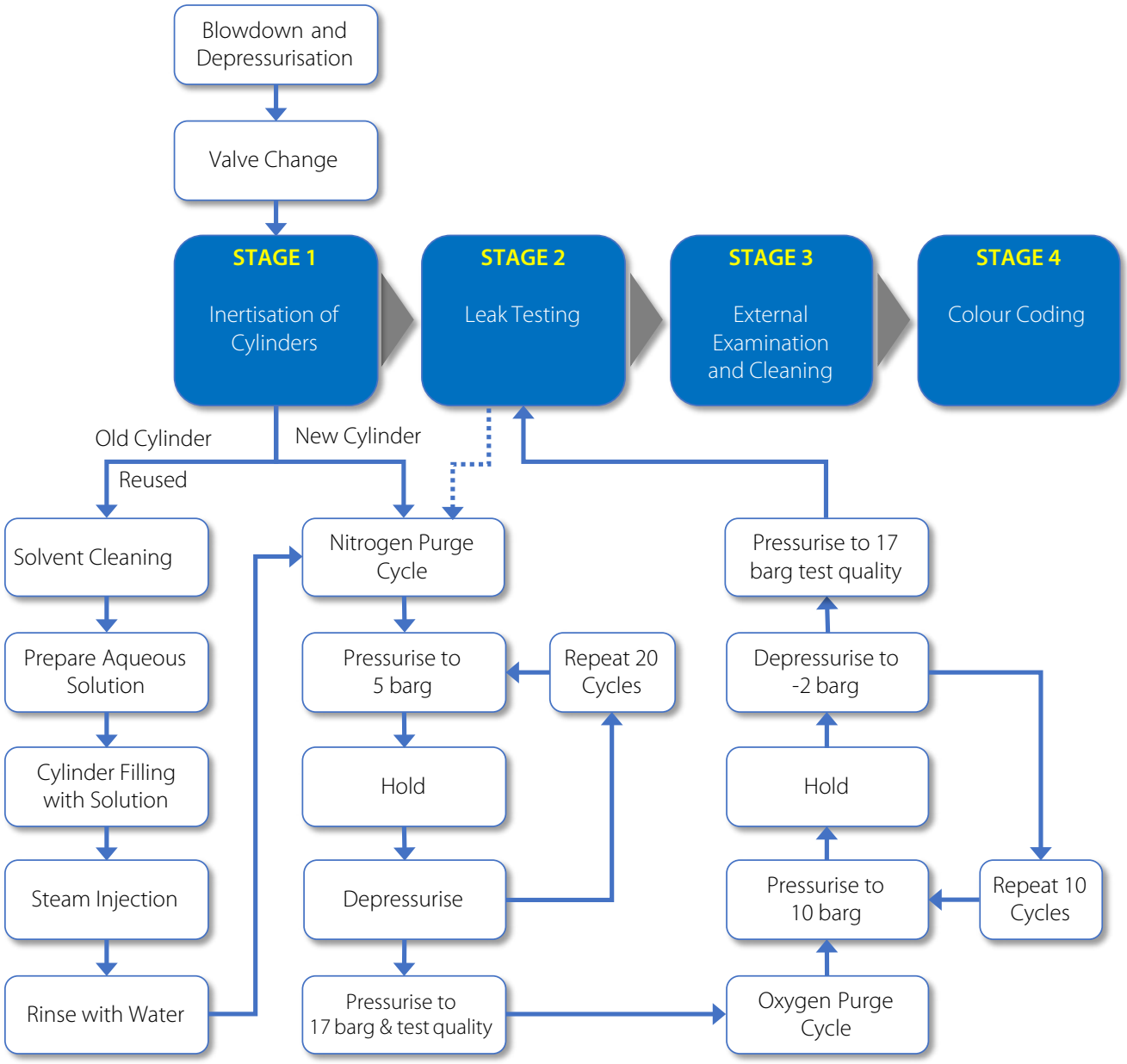


Figure-1: Overall Stages of Cylinder Conversion SOP

Stage 1 - Inertisation of Cylinders

LPG cylinders are designed, and fabricated following IS 3196 from steels conforming to IS 6240 / IS 15914. These standards, however, do not cover cleanliness criteria and certification in terms of removal of oil traces, moisture content, particulates etc. Typically, cylinders are designed and fabricated to store specific gases. Still, most of the cylinders can be transferred from one gas service to another, provided applicable regulations are observed, and appropriate procedures are followed considering material compatibilities. Cylinders that have been in service may have been exposed to conditions that can prove unsafe while transferring to different gas services. These conditions could result in contamination, corrosion or residual gases that may be hazardous or harmful.

Utmost care shall be taken in ensuring proper purging or cleaning procedures are followed to remove residual gas, contaminants or corrosion products and cleaning agents. Cylinders are dried and sealed to prevent the entry of dirt and moisture once cleaned. Due to potential safety issues like corrosion, contamination and compatibility, specific actions are required when transferring a cylinder from one gas service to another. The cleanliness check and qualification become even more critical when patients consume the gas for medical/lifesaving reasons.

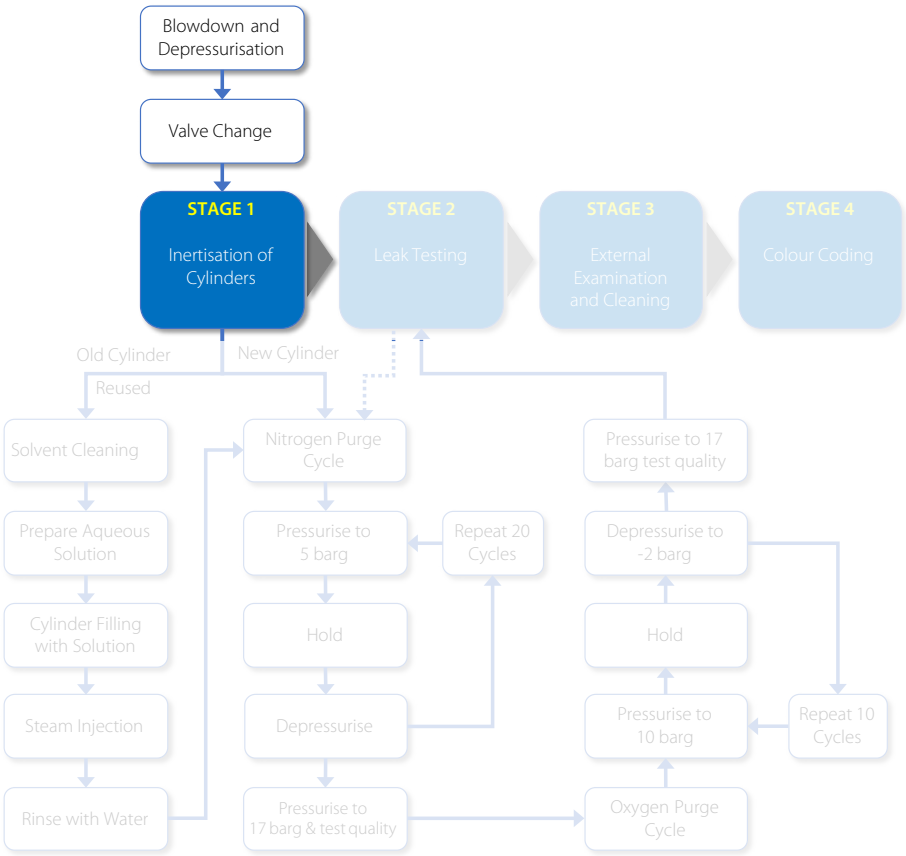


Figure-2: Preparation for Inertisation

Preparation for Inertisation

Depressurisation and Valve replacement shall be carried out before the inertisation procedure is started. Refer to Figure 2, indicating the steps involved for pre-preparation before inertisation is begun.

- When used cylinders are to be converted, it is essential to empty the residual contents of the LPG cylinder. Reduce the pressure (blowdown) to atmospheric pressure using appropriate equipment and discharge LPG to safer locations meeting environmental requirements
- The LPG cylinders are fitted with standard regulators having non-return valves, and two-way gas purging (in and out) is not possible. Standard commercial, industrial neck valves (1-inch NPT) shall be mounted, as used in standard 50 Litres D-type gaseous oxygen cylinders.
- Adequate removal of flammable gas below its lower flammable limit can be achieved by evacuation, purging, filling with water, and subsequent emptying and drying.

Inertisation Procedure:

LPG cylinders are inertised using the following three sets of preparations before utilising them for oxygen storage.

1. **Solvent Cleaning:** Recommended only for used cylinders
2. **Nitrogen Purge Cycle:** To remove the impurities by purging the cylinders with nitrogen and to analyse the moisture content, Oil content & mechanical impurities in the cylinders after purging. A quality check is performed to ensure that the nitrogen is not contaminated after completing the nitrogen purge cycle.
3. **Oxygen Purge Cycle:** To condition the cylinders with gaseous oxygen and check for contamination.

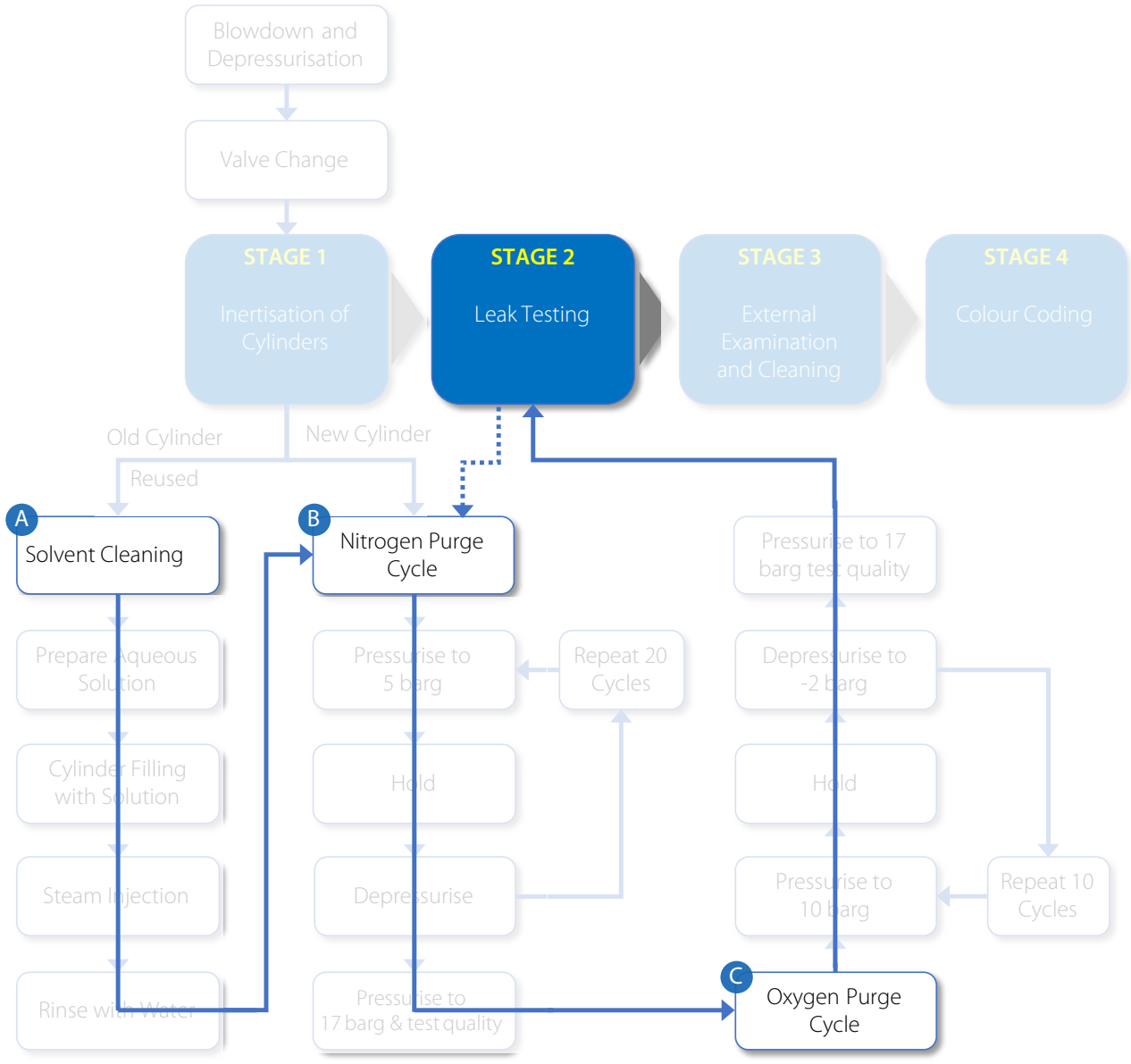


Figure 3: Inertisation Procedure

The SOP for the three sets described in Figure 3 is as below.

A Solvent Cleaning of Internal Surfaces:

1. The cylinder shall be taken for an internal visual inspection for any evidence of a liquid or a hydrocarbon presence. Liquids may show as pools on the cylinder bottom or as droplets on the wall. Hydrocarbons may show as liquids or by an oily appearance. If similar conditions are observed, the cylinder shall be cleaned with solvents. This solvent cleaning procedure is recommended only when the used LPG cylinders are converted for oxygen service. After solvent cleaning, the internal inspection shall be repeated to ensure that the observed contamination and the cleaning solution have been removed.

2. The used LPG cylinders may have hydrocarbons and liquid water content present. Due to the presence of water, the internal surface might experience corrosion. The corrosion and hydrocarbons need to be removed from the cylinders before using them for oxygen services. This can be achieved through solvents.

3. Several aqueous solutions may be used for removing organic materials from cylinder interiors. These are based on alkaline solutions of sodium metasilicate, potassium or sodium hydroxide solution. An alkaline detergent does not necessarily dissolve oil, grease or similar contamination. Cleaning solutions have high wetting properties that enable them to emulsify oil films and coat all objects with a detergent film so that the oil floats free in the solution. Some means of removing surface films should be provided, as the cleaning action brings much of the contaminants to the surface of the liquid. The following paragraphs describe the cleaning procedure for one such solution.

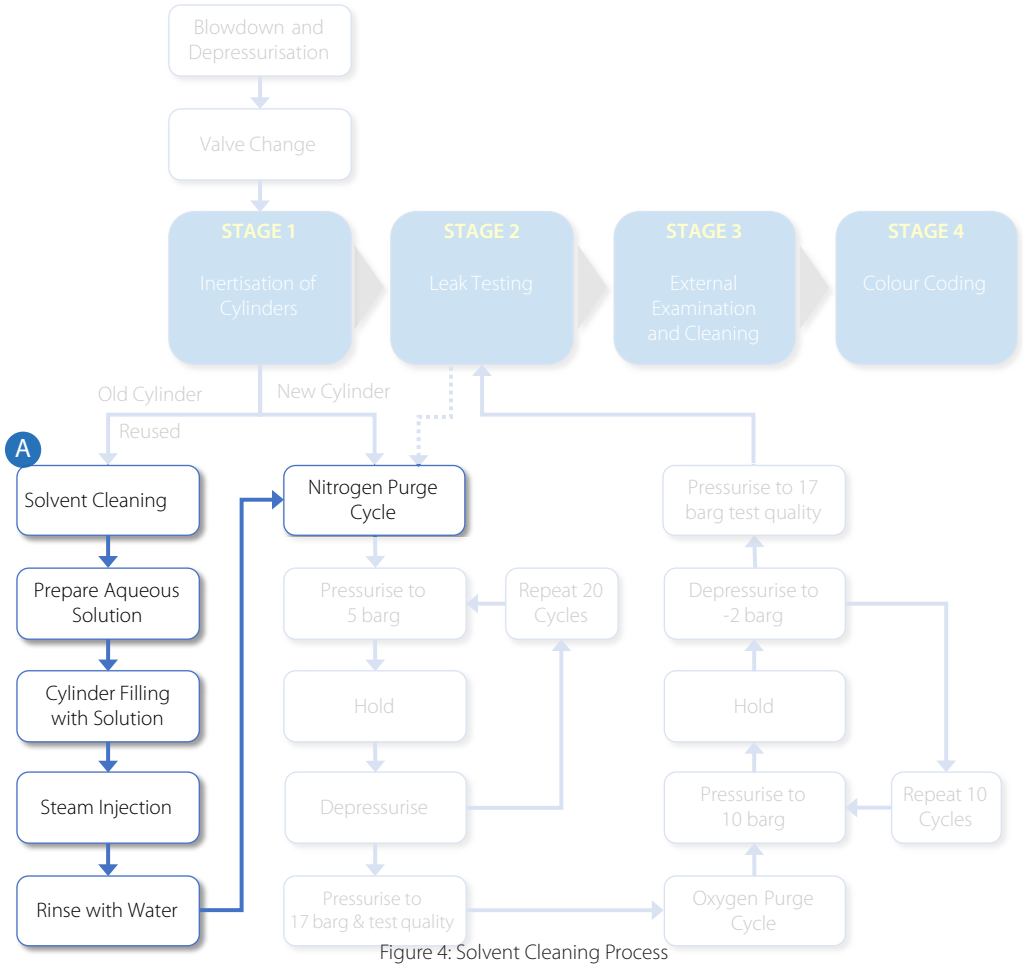


Figure 4: Solvent Cleaning Process

To prepare a high concentration cleaning solution, 1 kg of sodium metasilicate and 30 g of sodium dichromate are added in every 20 litres of clean water. This mixture forms about 5% concentration. The strength of the cleaning solution should not be greater than that required for effective cleaning. For example, if the contamination is a light oil, a solution of 150 g to 200 g of sodium metasilicate in 20 litres of water is adequate.

Sodium metasilicate forms insoluble precipitates with the mineral salts in water. If the water used is exceptionally hard, these precipitates should be removed from the cleaning solution by filtration to avoid clogging the equipment. The alkaline solution used for cleaning should be freshly prepared and shall not have been previously used.

Internal Cleaning with Steam: A steam lance is inserted to the bottom of the cylinder filled with an alkaline solution. Clean, oil-free steam is injected into the solution through the lance to keep it boiling for 15 min to 30 min. During the boiling process, enough excess boiling water or steam is injected through the lance so that the solution overflows from the cylinder, carrying away the contaminants which have floated to the surface.

The cylinder is then inverted, with the open neck pointing downwards. A mixture of high-pressure steam and a cleaning solution is injected into the cylinder through a steam lance. The lance should be moved up and down and sideways so that the cleaning fluid will contact the entire inner surface of the cylinder. Rotating the cylinder may be helpful in effective cleaning.

After cleaning with an aqueous or alkaline solution, the cylinder must be thoroughly rinsed with clean water. Thoroughly dry the cylinder immediately after rinsing using the nitrogen purge method described earlier

B Nitrogen Purge Cycle:

The LPG cylinders are purged by nitrogen gas with pressure ranging from 0 to 5 bar(g) for 20 purge cycles. This process removes all the particulate impurities and brings the moisture content within the cylinder closer to the acceptable limits.

The cylinders are filled with nitrogen to 17 bar (g), and a sample is collected on completion of cleanliness check. Analyse the moisture content, Oil content & mechanical impurities in the cylinders after completion of purging. Each cylinder shall be sufficiently dry so that liquid water will not form within the cylinder at the pressure and temperature ranges of oxygen. The presence of excessive moisture can be rectified by drying the cylinder. As per Indian pharmacopoeia, the moisture specification for medical grade oxygen is less than minus 40 deg C dew point temperature. A moisture test for dew point shall verify this.

It is recommended to carry out an appropriate NDT evaluation (e.g. shear-wave ultrasonic or acoustic emission testing). Those cylinders passing these tests may be transferred to the oxygen service.

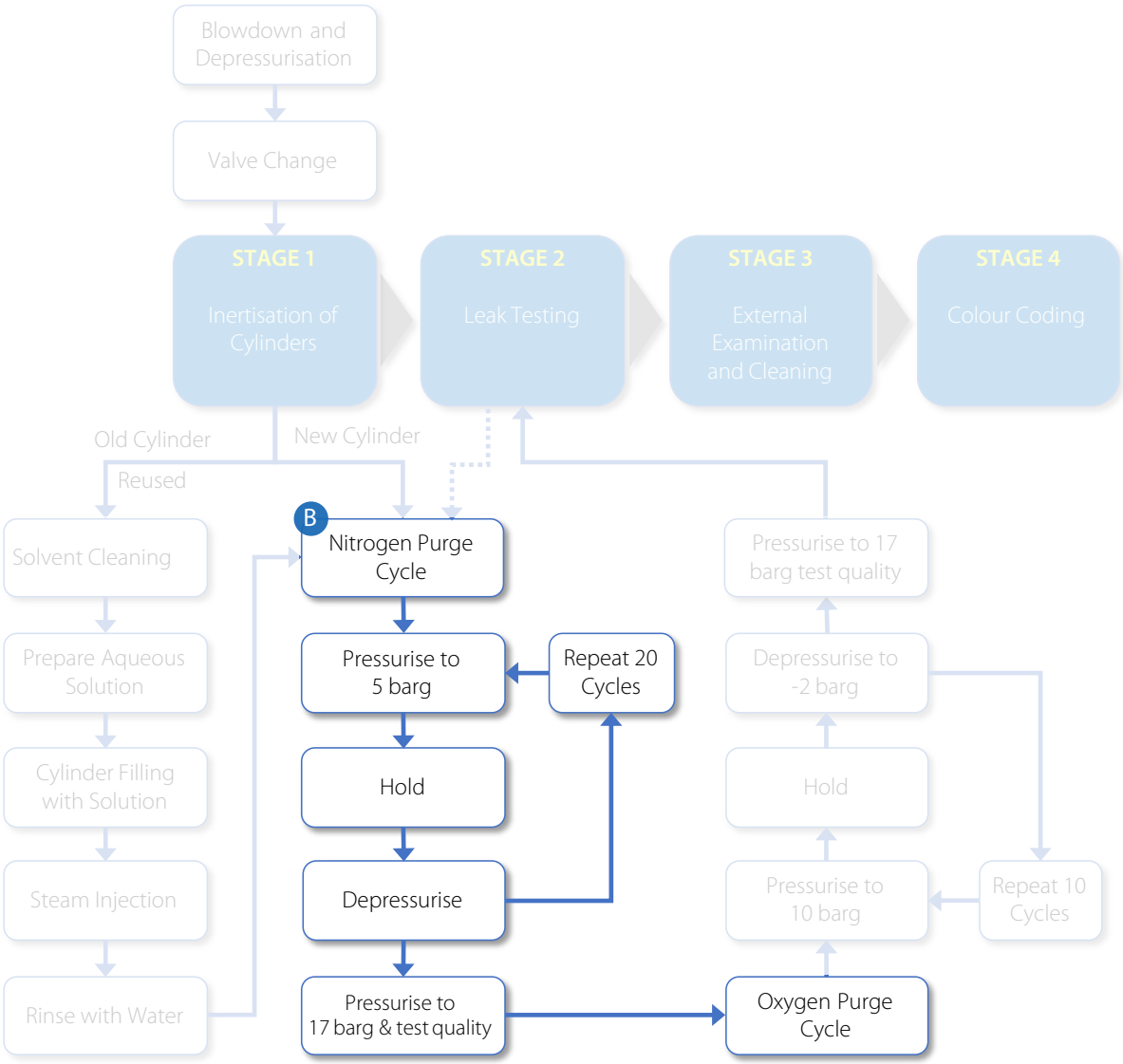


Figure 5: Nitrogen Purge Cycle

C Oxygen Purge Cycle:

The cylinders shall be purged with oxygen gas for 10 cycles at 2-10 bar(g) pressure. After nitrogen purging cycles, the cylinders are subjected to gaseous oxygen purging in which a similar pattern of pressurisation, hold, and depressurisation of the cylinders shall be followed. This O2 purging ensures the conditioning and acceptability of the LPG cylinders for medical oxygen use. Finally, the oxygen can be tested for medical-grade quality, and the cylinder can be certified for reuse when acceptable quality parameters are observed.

The procedure adopted shall help in making the cylinders moisture-free. To ensure the continuity of this conditioning, the cylinders must be preserved with oxygen at a nominal pressure of 0.5 bar(g). The higher pressure in the cylinder than the atmosphere will ensure no moisture/ impurities from the atmosphere flow into the cylinder. The dew point of the Oxygen at the delivery port must be continuously monitored.

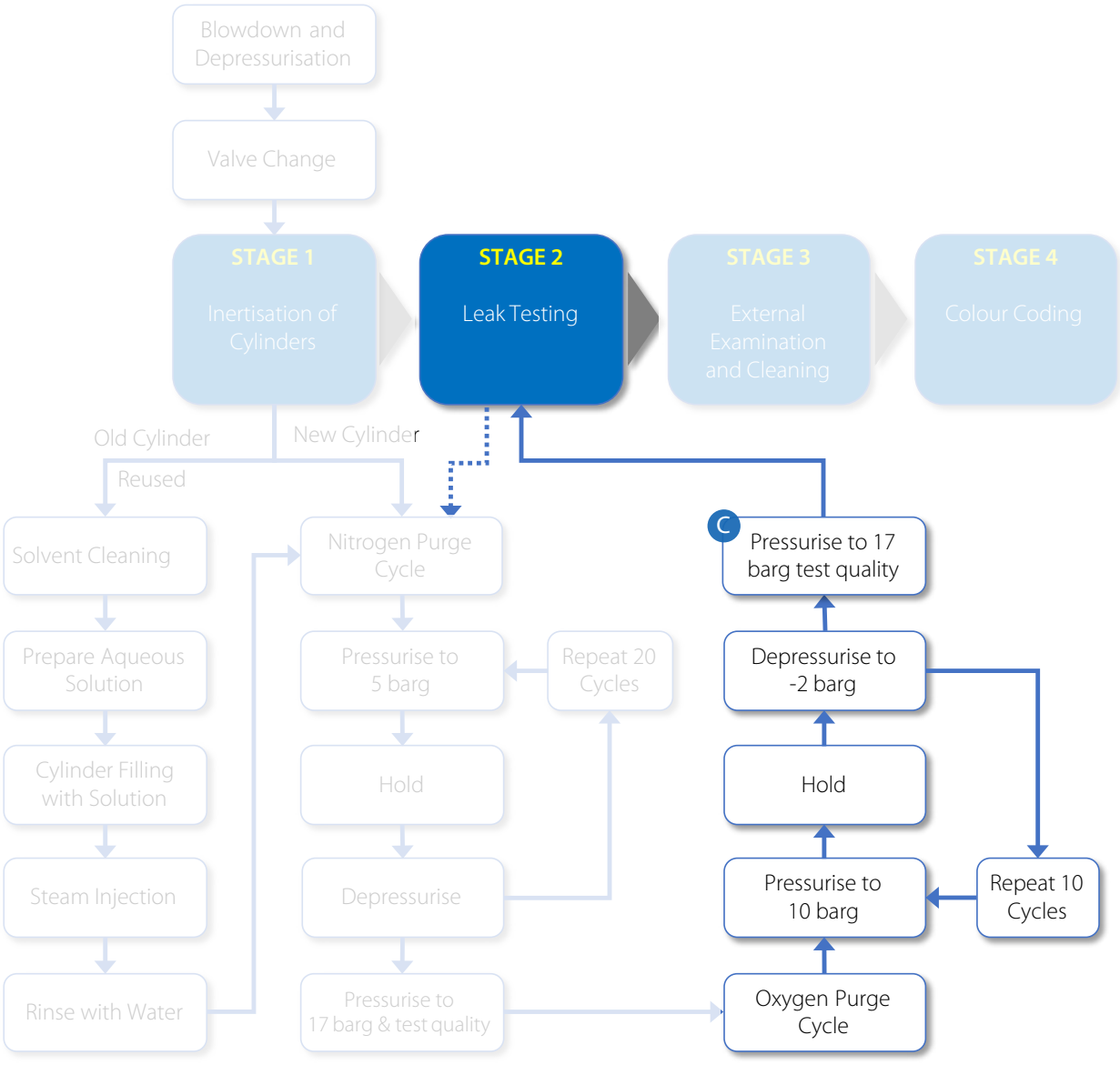


Figure 6: Oxygen Purge Cycles

Stage 2 - Leak Testing

The pneumatic leak tests shall be conducted as part of the qualification of LPG Cylinders for oxygen use and testify the cylinders' leak tightness. The following procedure shall be carried out.

Fill the cylinders with oxygen gas at a nominal pressure of 0.5 barg and observe for any leakages. In case of any leakage during preservation or transportation, there is no harm/damage. Oxygen is a non-toxic, breathable and hazardous gas. Identify the leakage and get it rectified before filling the cylinder with Oxygen. The leak may be due to two reasons:

- **Body leak of the cylinder:** The procedure to be adopted for leak arrest is likely to depend on the severity of the leak rate. In case the leak is beyond the acceptable limits, the cylinder may be rejected. A soap bubble test will qualify the same.
- **Leak at the neck valve:** On identifying the leak at the Neck or Valve, the cylinder shall be first isolated, and the oxygen shall be completely vented in a normal ventilated atmosphere. The valve shall be replaced and tested again for leak tightness.

Nitrogen purging needs to be carried out to expel the traces of hydrocarbons and oil that may be present from LPG cylinders. The preservation of cylinders at minimal positive pressure prevents the entry of oil and hydrocarbons from the atmosphere, apart from moisture. The same procedure of nitrogen purging (See figure 5 above) must be repeated each time after completing periodic hydro and pneumatic tests of the cylinders, as per the PESO norms. This will ensure the protection of the cylinders against flammability.

Stage 3 - External Examination and Cleaning

This step is required for each cylinder that is identified for storing oxygen. The external examination shall be carried out to assess transport damages & conditioning of the cylinders and perform cleanliness checks to assess impurities.

It is recommended to carry out an external visual inspection of the cylinder and valve to verify suitability for service. ISO 6406, ISO 10460 and ISO 10461 may be referred for guidance. Following checklist to be used.

- Check the working pressure/cylinder design specification and applicable regulations to verify that the cylinder is satisfactory and authorised for oxygen service.
- Check the cylinder ownership to verify that the owner has authorised the transfer to oxygen service.
- Check the test date and determine whether it is within the specified test frequency for the old and new gas services. Retest the cylinder as necessary.
- Remove all means of identification concerning the LPG, such as labels, colour coding and other relevant markings. Stampings of LPG shall be removed.
- **External cleaning** - Cylinders coated with dirt, oil or grease, but showing no evidence of such contamination on or in the vicinity of the valve outlet, maybe cleaned only externally. The alkaline solution may be applied with a brush or rag, which will effectively remove most contaminants. Care should be observed that none of the solution or dirt gets on or into the valve. After all contamination has been removed, rinse the cylinder thoroughly with clean, warm water.

Procedure for Mechanical Cleaning

Internal inspection indicates rust, mill scale or other foreign solids adhering to the walls and are difficult to remove through solvents. In that case, such material should be removed by mechanical cleaning before the internal cylinder surface is again cleaned using a solvent. Few mechanical-cleaning procedures are described below;

- **Wire Brushing** - The interior of cylinders can be cleaned by inserting a wire brush of proper design through the cylinder neck opening and rotating it with an electric drilling machine while forcing the brush against the wall of the cylinder and moving it or the cylinder up and down to clean all interior surfaces. The cylinder should be inverted periodically to dump out any loose material.
- **Tumbling** - A quantity of hard abrasive material, such as angular chilled cast iron, short reinforcing rod pieces, etc., is placed inside the cylinder. Rotation combined with a rocking or shaking motion which causes the abrasive materials to strike the inner walls of the cylinder, is preferred. The cylinder is then rotated in a horizontal position for a sufficient period to loosen the material adhering to the walls. The preferred rotation should not be completely circular since such action would make the abrasive material slide on the inner surface without impinging action that gives superior cleaning.
- **Shot Blasting** - Shot blasting is a method of removing mill scale or corrosion products from cylinder interiors. Care must be taken not to remove excessive amount of parent metal from the cylinder walls. This method works best when the cylinder is inverted so that the shot and loose material do not accumulate within the cylinder. The motion of the blast nozzle relative to the cylinder surface should be constant and uniform over the entire surface to be cleaned. The motion should never be stopped during the cleaning operation to avoid excessive local metal loss of the cylinder wall.
- Following any mechanical cleaning method, the cylinder should be inverted to remove loose particles, then rinsed well with clean water and dried. Install a plug or the proper valve immediately after drying.

Stage 4 - Colour Coding

The converted Cylinders shall be painted for oxygen service, including painting, labelling, stencilling and possibly stamp marking of the cylinder as per IS 3933. The PESO approval stamping shall also form the part of the converted LPG cylinder for storing oxygen.

Colour Codes medical gas cylinders in India are shown in Figure 7 and given below.

- White shoulder and graphite black body contain medical oxygen.
- Blue shoulder and blue body contain nitrous oxide.
- Black shoulder and Grey body contain nitrogen.

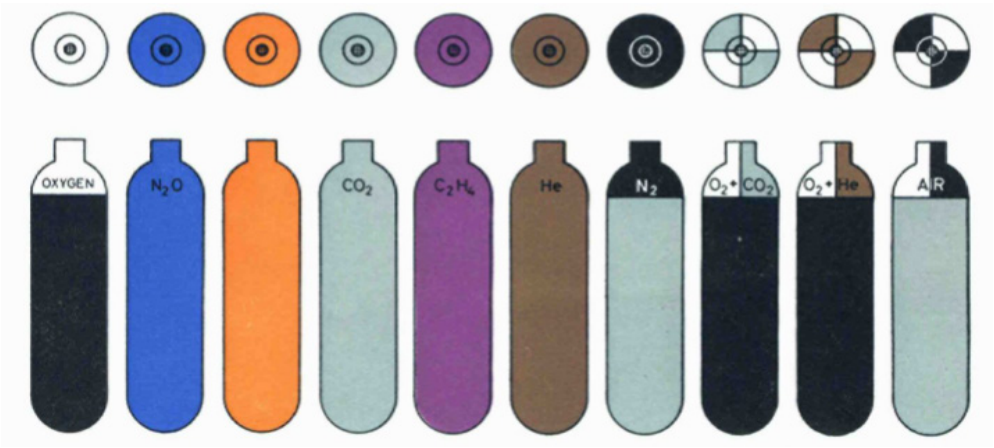
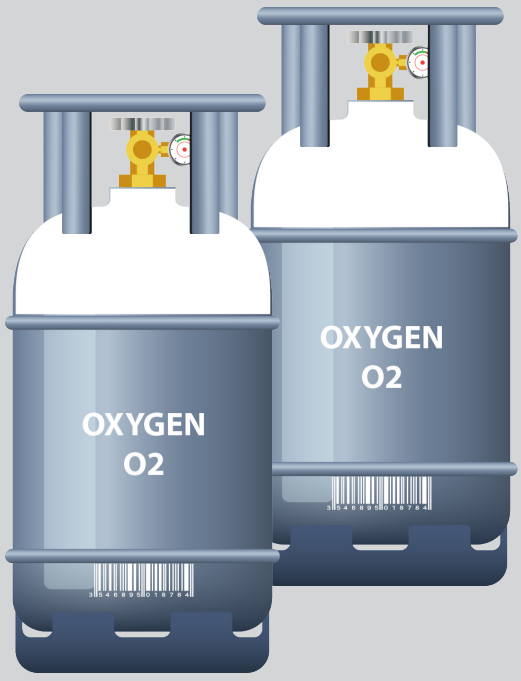


Figure 7: Colour Codes medical gas cylinders in India

Cylinders shall be legibly and permanently marked, preferably at the valve end of the cylinder and shall extend down the cylinder to the shoulder. The chemical formulae and name of the gas it contains and UN Number shall also be marked.

The marking shall not be made on the body of the cylinder but shall be at areas in the formed neck where the thickness of metal is greater than the design minimum and where it is adequate for marking to be carried. The manufacturer's identification, however, may be marked on the base.



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Author

Atul Choudhari - Sr. General Manager

Shireesh S Swami - Sr. General Manager

Tata Consulting Engineers Limited (TCE)
tceconnect@tce.co.in

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TATA CONSULTING ENGINEERS LIMITED

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Corporate Office: Unit No NB 1502 & SB -1501, 15th floor, Empire Tower,
Cloud City Campus, GUT NO 31, Village Elthan, Kalwa Industrial Estate,
Thane Belapur Road Airoli, Navi Mumbai – 400708.
Email: tceconnect@tce.co.in | Website: www.tce.co.in

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