

TATA CONSULTING ENGINEERS LIMITED

ENGINEERING A BETTER TOMORROW OVER FIVE DECADES

TCE Emergency Response for Gaseous Oxygen Storage and Distribution

First Version released 20th April 2021

Current Version - 230521v2



TATA CONSULTING ENGINEERS LIMITED

ENGINEERING A BETTER TOMORROW



Emergency Options for Medical Oxygen Storage, Distribution & Usage

This presentation is an abridged version and must be read after having read the detailed White paper : https://www.tce.co.in/wp-content/uploads/2021/04/Meeting-Oxygen-Demand-Tata-Consulting-Engineers-Response.pdf

WE MUST COME TOGETHER AND HELP WITH HOPE AND POSITIVITY

CONFIDENTIAL 2 🔇 🕥

Covid Aid 2020 Efforts:

Engineering Consultancy by Tata Consulting Engineers (TCE)



COVID MODULAR Hospitals







Opensource Ventilators

- Multiple Ventilator design were studied feasibility under emergency conditions was evaluated (No prototypes were done only feasibility evaluations)
- 2. <u>OpenSource Medtronics</u> <u>Ventilator</u> was finally zeroed upon and manufacturing firms were conveyed to explore tie-up and manufacturing

COVID JUMBO Hospitals







COVID 2021 Second Wave - Medical Oxygen - Challenges Faced





Other Options - Exhausted







Centralized Cryogenic Generation-Distribution is Bottleneck

Inadequate In situ Generation at Hospitals





FOR IMPORTING NEW UNITS

Alternate and out of box solutions for Oxygen **GENERATION** and **DISTRIBUTION** is Crucial

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Covid Aid 2021 Efforts:

CLICK for DETAILS

PSAN2O2 & PSAO2

Innovative open source solution for Plant scale Oxygen generation

- 1. Conceptualised an innovative idea and engineered the conversion of existing PSA Nitrogen plants to PSA Oxygen plants
- 2. Implemented successful pilot with IIT Bombay in 03 days
- 3. Partnered with Tata Chemical for required sourcing of Zeolite from Europe
- 4. With the support of Min of Commerce, PSA, DSIR & CSIR received GOI IAF support for urgent airlifting of a critical resource for the conversion
- 5. Ongoing program under Min of Environment, CPCB, TCE is project managing feasibility of more than 150+ plant (80,000 LPM) conversion across India, with 65 confirmed plants (35,000 LPM) as on date
- 6. and providing technical expertise, design guidance and consulting to 1500+ teams across India in their endeavour to solve the oxygen crisis, Technical Specs, zeolite procurement & assistance for NEW oxygen plants

This Presentation

C20

Solutions for effective Oxygen supply chain

- by proposing an innovative solution of using existing cylinders (LPG/CO₂) for Oxygen distribution
- 2. by leveraging the existing supply chain of LPG / CNG for Oxygen supply across the country



CLICK for DETAILS

O2C

Solution for portable Oxygen generation

- 1. Supporting MSME across India for mass manufacture of Oxygen Concentrators
- 2. Working prototype of Portable Oxygen Concentrator with an open-source design created in 05 days
- 100% indigenous concentrator supporting India's Atmanirbhar Vision
- 4. Prototype produces
 20 LPM @ 94%
 oxygen purity

Consulting on Oxygen Generation supply chain and capacity enhancement

- across various States, namely Rajasthan, Maharashtra, Uttar Pradesh, Odisha, Andhra Pradesh, Silvassa, Gujarat
- 2. to NGOs, hospitals including Tata Medical Centre for their Oxygen augmentation and readiness
- Emergency Modular Units with Oxygen, AC and Medical support



Emergency Oxygen Storage and Distribution : Ongoing Efforts



Use of CO₂ Fire Extinguisher Cylinders for Storage of Oxygen



Use of LPG Cylinders for storage of Oxygen



Pilot Project

Use of CNG Cylinders for storage of Oxygen

THESE CONVERSIONS CAN ONLY BE DONE BY GOVERNMENT AUTHORITIES.

All these methods INVOLVE Statutory, Legal and other APPROVALS. Proper cleaning and COLOUR coding of CYLINDERS is required for SAFETY reasons. A governance mechanism involving government officials, PESO, Controller of Explosives, Fire Department, Medical Department (Min. of Health) and administrative authorities is required for related compliances and approvals.

OUTCOME = 8000 MT of Oxygen Storage addition

1. 80 Lacs LPG Cylinders* (average O2 600 litres /cylinder)

Involved Authorities

2. 7200 MT

*India has ~40 Cr Household LPG Cylinders

This Conversion Program needs to be executed at a NATIONAL Scale to realize above numbers

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2. 600 MT

What is Needed?



CYLINDERS – Supply Chain for Distribution

- 1. Government approval and a Central GOVERNMENT BODY to take this forward
- APPROVAL: PESO, CPCB and other approval and SOP COLOUR coding need to be painted, certification of cylinder and tamper proof identification / Sealing (post filing of Oxygen) + proper Quality testing and SAFE usage of OXYGEN filled
- **3. SAFETY**: proper CYLINDER unique identifier and naming convention to ensure authentication of the lot using simple SMS and track and trace
- 4. VOLUME Possible: Nitrogen, Argon, and other cylinders already in use we are aiming to use CO2 Cylinders, CNG and LPG Cylinders are 40-50 Cr in numbers we can use approx. min 10% of these LAST MILE CONNECTIVITY / DISTRIBUTION beyond LOX Tankers / Other Containers
- 5. Leverage existing LPG bottling plant (SPARK-Resistant compressors, and well-established LPG distribution network for last mile connectivity across India.
- 6. ABOVE as emergency solution after exhausting options of Oxygen and currently approved Nitrogen and INERT gas industrial cylinders

LPG Cylinder Conversion – SAFETY / Tracking / Audit



SAFETY: CONVERSION with proper COLOURING - CYLINDER unique identifier and naming convention – to ensure authentication of the lot using simple SMS – and track and trace



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Why LPG cylinders?



- 1. India has approx. 40 Cr LPG Cylinders 2% ie 80 lacs of LPG Cylinders may be converted
- 2. 80 Lac LPG Cylinders will enable storage and transportation of 7000 MT of Oxygen
- 3. LPG Cylinders will be at max 20 BAR no complex air compressor required for 150-200 bar capacity can also be done with manual compressor
- 4. Stores upto 640 litres of oxygen in a LPG Cylinder
- 5. Existing LPG bottling plants across the country may be used
- 6. Simple conversion no changes needed except cleaning
- 7. Use same LPG regulator and connect to OXYGEN low pressure line at 1.2 BAR
- 8. Use NRB Masks and NOT CANNULA for ensuring Oxygen at higher concentration and NO to ZERO oxygen wastage
- 9. It is recommended that LPG Cylinder to be used ONLY as a CYLINDER BANK and with ONLY NRB masks and NOT CANNULA
- 10. Human intake is max 0.5-1 LPM except ventilator that forces higher oxygen for patients who are not critical and hence not on VENTILATOR LPG cylinder oxygen can be used
- 11. LPG Cylinder to use regulator with output at 1.2 BAR and max 5 LPM and with NRB Mask
- 12. Also use this setup with LPG cylinders for HOSPITALS that don't have existing oxygen line (which is at 4.5 bar for ventilator)

National Program using Converted LPG cylinders



- This Program has to be done on NATIONAL Scale with aim for 80 Lac LPG Cylinder Conversion for their use at HOSPITALS that do not have existing Oxygen supply and for Patients who are not Critical and needing between 1-5 LPM Oxygen only.
- 2. Railways network for transportation may be explored for both cylinder and modular unit transportation and the cylinders and units are to be unloaded at various stations across India. Cylinders are continuously replenished every 12-24 hours this is one of the possible mechanism to provide Oxygen across India
- 3. Also via road we use the **existing LPG distribution network of OIL Marketing company** to provide these Oxygen filled LPG Cylinders across Cities/ Villages
- **4. Modular container Covid units** with 5 beds AC and provision for oxygen cylinders OR converted CNG / LPG cylinders outside this with oxygen line connectivity provided
- 5. Number of cylinders to put outside this can be 20-30-40-60 etc such that 50% are connected and 50% ready for change over

CO₂ Fire Extinguisher Cylinders for Storage of Oxygen



CO ₂ Extinguisher Capacity (kg)	Min. Residence Time (Hrs)	Max. Residence Time (Hrs)	CO ₂ fire e suitable f
2	1.3	2.7	
3	2.1	4.2	• Bank
4.5	2.7	5.5	for hi

CO₂ fire extinguisher cylinders are suitable for medical oxygen w.r.t construction and Mechanical Integrity

Bank of multiple cylinders for high flow requirements

Website : http://peso.gov.in Email: explosives@explosives.gov.in दूरभाष/ Telephone : 0712-2510248 फ़ैक्स/ FAX : 2510577

कार्यालयीन उद्देश्य के सभी पत्रादि "मुख्य विस्फोटफ नियंत्रक" के पदनाम से भेंजे जाए उनके व्यक्तिग्व नाम से नहीं. All communications intended for his Office should be addressed to the 'Chief Controller of Explosives' and NOT to him by name. भारत सरकार GOVERNMENT OF INDIA पेट्रोलियम तथा विस्फोटक सुरक्षा संगठन Petroleum and Explosives Safety Organisation (पूर्व नाम – विस्फोटक विभाग) (Formerly- Department of Explosives) "ए-ब्लाक ú, पाँचवा तल, केन्द्रीय कार्यालय परिसर७, "A" Block, 5th Floor, CGO Complex, सेमिनरी हिल्स, नागपूर - 440 006 (महा) Seminary Hills, Nagpur- 440006

संख्या: D-21013/PBL/18-Exp

दिनांक /Nagpur, dated : 22/04/2020

<u>CIRCULAR</u>

Sub: Standard Operating Procedures (SOP) for conversion of Industrial Oxygen Cylinders and Inert Gas Cylinders (Nitrogen, Argon & Helium only) to Medical Oxygen Cylinders in the wake of COVID-19 pandemic- reg. O₂ supply to patients - 5lt/min and 10lt/min

PESO Guidance Can Be Suitably Used For Conversion

Nozzle need to be replaced with oxygen service nozzle; modify the threading on oxygen nozzles to match the CO_2 extinguisher nozzle – Else in case a CYLINDER BANK is being used – no changes needed. It is recommended to use CYLINDER BANK approach as opposed to individual Cylinders for both safety and time since it will not involve any nozzle changes



Plenty of Fire extinguisher are already available across – both under new production, or under usage at many locations, offices, Theatres, malls, etc.

LPG Cylinders for Storage of Medical Oxygen





Low Pressure Storage – Lower Residence Time.

Capacity	Min Res time (hr)	Max Res time (hr)
1 Domestic Cylinder	1.1	2.1

Basic Materials Of Construction are Suitable for Oxygen Service

- 1. LPG cylinders are widely available (~28.13Cr connections)
- 2. New / unused cylinder is preferred to avoid possibility of contamination
- Used cylinders during emergency Inertization (solvent-based cleaning), Purging with Nitrogen/air and drying is necessary



O₂ supply to patients - 5lt/min and 10lt/min



For requirement of higher oxygen, a bank of 10 - 50 cylinders may be used.

CNG Cylinders for Storage of Medical Oxygen





Integrity

Conversion Procedure

- Cleaning And Inertization
- Inspection •
- **Corrosion Checks** •
- Nozzle Replacement
- Hydrotest, Drying
- Painting •
- **Certification and** • **Approvals**

INTERNATIONAL STANDARD

ISO 11621 First edition 1997-04-15





Exterior Cleaning





STATUTORY **APPROVALS** BE **OBTAINED** –

(PESO CCOE, Etc)

Equipment for internal inspection of LPG cylinders



Painting





Nozzle Replacement

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LPG Cylinder Bank

For details - Please use this LINK:

LPG Cylinder White Paper



Bill of Quantities for Cylinder Bank

Sr. No.	Item Description	Specification	Name of Suppliers
1.	LPG Cylinders	Domestic LPG Cylinder of 14.2 kg storage	HPCL/BPCL/IOCL
2.	Manifold till regulator	25NB (1") conforming to ASTM A-312 TP304.	United/Greentech
3.	Adaptor	Body - Pressure die-cast from zinc alloy. Brass parts shall be from free cutting brass bar. Rubber components from nitrile rubber conforming to IS 9798.	United, SKN, Vanaz, Nova Comet, Medas Gas
4.	Flexible Wire-Braided Cylinder Pigtail	Rubber tube - Synthetic & acryl nitrate butadiene rubber and compatible to Oxygen. Brass nuts - Forged from wrought or extruded sections.	Markwell, United
5.	Non-Return Valve (NRV)	Body – Bronze, Disc – Bronze	SKN, United, leader
6.	Pressure Gauge with isolation valves	Dial – 4", Pressure Range - 0 to 10 bar(g)	Donfoss, Alot,
7.	Manifold Isolation Ball Valve	Body – Cast Steel	Audco, Leader, Hawa
8.	Automatic Changeover Valve with	Outlet pressure is adjustable between 0.5 bar(g) to 1 bar(g). The flow rate is between 20 to	United, SKN, Vanaz, Nova Comet,
	Adjustable Regulator	50 kg/hr. Body & cover is made from die cast zinc alloy. Diaphragm & valve pad from synthetic nitrile rubber conforming to IS:9798	Medas Gas
9.	ACF, Fine filter & Sterile Filter	304 stainless steel construction, 0.01 micron filtration, Organisms, oil, dirt with efficiency in access of 99.99%	Walker. Parker
10.	Gas Meter	Conform to BS 4161 Part 5. Maximum outlet pressure is 0.1 bar(g). Normal working pressure range is 0.020 to 0.05bar(g). Max gas flow rate is 2.5 Nm ³ /hr Minimum rate is 0.016 Nm ³ /hr.	Raychem RPG / ITRON

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Things to READ and Keep in Mind

https://www.indiacovidsos.org/oxygen1





Considerations for oxygen use

For management of COVID-19 [Version 5.3]

This guide is for staff in charge of patients who are on oxygen therapy. This is not a replacement for in-depth training but to be used as a quick reference guide. Combine with prone positioning as tolerated.





WITH Converted LPG Cylinders for Oxygen Storage : ONLY Reservoir Mask to be used with max 5 LPM and regulator pressure of 1.2 barg



OXYGEN CYLINDER CHECKLIST:

https://www.indiacovidsos.org/oxygen1#cylindersafety

SAFETY – DO NOT EXPLORE ELECTROLYSIS OXYGEN GENERATION METHOD for MEDICAL GRADE OXYGEN – <u>CLICK LINK for DETAILS</u>





Reservoir mask



WITH Converted LPG Cylinders for Oxygen Storage : ONLY Reservoir Mask to be used with max 5 LPM and regulator pressure of 1.2 barg



Reservoir mask

WITH Converted LPG Cylinders for Oxygen Storage : ONLY Reservoir Mask to be used with max 5 LPM and regulator pressure of 1.2 barg





Reservoir mask



WITH Converted LPG Cylinders for Oxygen Storage : ONLY Reservoir Mask to be used with max 5 LPM and regulator pressure of 1.2 barg

Illustrative Image: Use of Modular Units at Railway Stations





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Source: https://ncdc.gov.in/WriteReadData/l892s/90542653311584546120.pdf https://ncdc.gov.in/WriteReadData/l892s/42417646181584529159.pdf

Illustrative Image: Use of Modular Units at PLAYGROUNDs





LPG Cylinder Calculations

LPG Cylinder for Oxygen			Converted Cylinders - Distribution Potential			
Temp of O avlinder filling	00	20	Oxygen Supply Rate	*LPM	5	
r emp. of O ₂ cynnder mining		30	Pasidanaa Tima in One Cylindar	min	121.5	
Cylinder Pressure	kg/cm ² a	21		hr	2.0	
Supply Pressure - Outlet	kg/cm ² a	1.2	Number of Cylinders required for SINGLE	No.a	11.0	
Supply Tomporature Outlot	00	40	Patient in 24 hours @*LPM	INO.S	11.9	
	Q Qty. of O_2 that per Day for a Patient		ka/day	10.5		
	kgs		@*LPM	ky/uay	10.5	
O ₂ Mass Stored in Pressurized Cylinder		0.89	O ₂ Qty. that 1 Lakh Cylinders Can Supply	that 1 Lakh Cylinders Can Supply MT/day	89	
			in a Day			
Volume of O ₂ available for supply at given outlet			Properties			
temp & press	Ltr	607	Water Capacity of LPG Cylinder	Ltr m ³	33.6	
LPG Cylinder Bank for Oxyge	n		Molecular Weight kg/k		32	
No of cylinders in bank	No	40	Gas Constant, R	L.atm.mol ⁻¹ .K ⁻¹	0.08205	
No of Patients being served by 1 bank (of 40 LPG	No	5				
Cylinder Bank)	NU	5				
Volumetric Capacity	Ltr	24296				
Residence time of one Bank - for 5 Patients	hr	16				

Oxygen Density Calculator						
Temperature	⁰ C	20				
Pressure	kg/cm ² a	21.033				
Density	kg/m ³	27.36				

Please download excel for calculation

Oxygei	n Density I	adies
Temp.	Pressure	Density
0 ⁰	kg/cm ² a	kg/m ³
15	1.033	1.37
15	16.033	21.21
15	17.033	22.54
15	18.033	23.86
15	19.033	25.18
15	20.033	26.51
15	21.033	27.83
20	1.033	1.34
20	16.033	20.85
20	17.033	22.15
20	18.033	23.45
20	19.033	24.75
20	20.033	26.06
20	21.033	27.36
35	1.033	1.28
35	16.033	19.84
35	17.033	21.08
35	18.033	22.31
35	19.033	23.55
35	20.033	24.79
35	21.033	26.02
40	1.033	1.26
40	16.033	19.52
40	17.033	20.74
40	18.033	21.96
40	19.033	23.17
40	20.033	24.39
40	21.033	25.61



Compressibility Factor, Z					
Z	Pressure	Temp			
	atm	⁰ C			
0.9993	1	17			
0.9994	1	27			
0.9995	1	37			
0.9996	1	47			
0.994	10	17			
0.995	10	27			
0.9959	10	37			
0.997	10	47			
0.9773	40	17			
0.9813	40	27			
0.9848	40	37			
0.9879	40	47			
Conside	r Z equal to	0.99			
	Z 0.9993 0.9994 0.9995 0.9996 0.994 0.995 0.9959 0.997 0.9773 0.9813 0.9848 0.9879 Conside	Z Pressure atm 0.9993 1 0.9994 1 1 0.9995 1 1 0.9996 1 1 0.9995 10 1 0.9995 10 10 0.995 10 0 0.995 10 0 0.997 10 0 0.997 40 0 0.9848 40 0 0.9879 40 Consider Z equal to			

Material and Type of Construction for LPG Cylinder

Carbon

LPG cylinders conform to IS 3196 and are manufactured from low carbon steel of welded construction. The steel sheet conforms to IS 6240/ IS 15914 as per the details given below.

IS 6240: Hot Rolled Steel Plate (up to 6 mm) Sheet and Strip for the Manufacture of Low-Pressure Liquefiable Gas Cylinders

Table 1 Chemical Composition (Clauses 6.1 and 6.2) Constituent, Percent

Silicon

Constituent Percent

Sulphur

Phosphorus

Max

(6)

0.025

Aluminium

Min

(7)

0.020

Max	Min	Max	Max	
(2)	(3)	(4)	(5)	
0.16	0.30	0.25	0.025	

Manganese

NOTES:

Grade

(1)

1

- Elements not listed in this table may not be added intentionally to the steel. All suitable arrangements are to be made to prevent such elements being added from scrap or other materials used during manufacture, which impair the mechanical properties and usability.
- Steel maybe supplied with the addition of micro-alloying elements like niobium, titanium, and vanadium. The micro-alloying elements shall not exceed 0.10 percent when added individually or in combination.
- The nitrogen content of the steel shall not be more than 0.009 percent. This has to be ensured by the manufacturer oy occasional check analysis.

https://www.tce.co.in/sopconvert-lpg-cylinders/

to Oxygen:

Please read the SOP for

converting LPG Cylinders

Please read the detailed White paper :

https://www.tce.co.in/wpcontent/uploads/2021/04/ Meeting-Oxygen-Demand-Tata-Consulting-Engineers-Response.pdf



Tensile Strength MPa Yield Stress MPa		Percentage Elongation at Gauge Length s.Gs S:	Internal Diameter of Bend
	Min	Min	Max
(1)	(2)	(3)	(4)
350 - 450	240	25	t

NOTE - Where 't' is the thickness oftest piece.

IS 15914: High Tensile Strength Flat Rolled Steel Plate (Up To 6 mm), Sheet and Strip for the Manufacture of Welded Gas Cylinder

Table 1 Chemical Composition (Clauses 5.2, 6.1 and 6.2)

		Constituent, Percent					
S. No.	Grade	Carbon Manganese Silicon Sulphur Phosphorus Alur					
		Max	Min	Max	Max	Max	Min
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i	HS 235	0.16	0.30	0.25	0.025	0.025	0.015
ii	HS 265	0.18	0.40	0.30	0.025	0.025	0.015
iii	HS 295	0.19	0.50	0.35	0.025	0.025	0.015
iv	HS 345	0.20	0.70	0.45	0.025	0.025	0.015

NOTES:

 Elements not listed in this table may not be added intentionally to the steel. All suitable arrangements are to be made to prevent such elements being added from scrap or other materials used during manufacture, which impair the mechanical properties and usability

- Steel may be supplied with the addition of micro-alloying elements like niobium, titanium, vanadium and boron. The micro-alloying elements shall not exceed 0.10 percent when added individually or in combination.
- 3. The nitrogen content of the steel shall not be more than 0.009 percent. This has to be ensured by the manufacturer by occasional check analysis



Please read the detailed White paper :

https://www.tce.co.in/wpcontent/uploads/2021/04/ Meeting-Oxygen-Demand-Tata-Consulting-Engineers-Response.pdf

Please read the SOP for converting LPG Cylinders to Oxygen:

https://www.tce.co.in/sopconvert-lpg-cylinders/

Grade	Constituent Percent					
S. No. Grade		Tensile Strength Yield Stress MPa	Yield Stress MPa Min	Percent Elongation at Gauge Length Min		Reference Heat Treatment
				< 3MM (see Note 2)	3 to 6 mm (see Note 3)	Temperature
i	HS 235	360 - 460	235	22	30	920 - 960
ii	HS 265	410 - 510	265	20	28	890 - 930
	HS 295	450 - 560	295	18	26	890 - 930
iv	HS 345	490 - 610	345	17	24	880 - 920

NOTES:

- The above properties are specified for flat rolled steel and should meet the properties of normalized (Time at austenitizing temperature approximately 2 min/mm of plate thickness) / stress relieved (Time at stress relieving temperature: as prescribed for Indian domestic cylinder) cylinders. Considering the drop in the normalizing, tensile properties of flat rolled products are to be mutually agreed upon between the cylinder manufacturers and steel producers for normalizes cylinders
- Percentage elongation for products of thickness less than 3 mm, is calculated based on test pieces with a width of 20 mm and a gauge length of 80 mm
- Percentage elongation for products of thickness 3 to 6 mm, is calculated based on test pieces with a gauge length of Lo = 5.65 S₀ (S₀ is the initial cross-sectional area of the test piece)

Please read the SOP for converting LPG Cylinders to Oxygen:

Please read the detailed

https://www.tce.co.in/wpcontent/uploads/2021/04/

Demand-Tata-Consulting-Engineers-Response.pdf

White paper :

Meeting-Oxygen-

https://www.tce.co.in/sopconvert-lpg-cylinders/



For Further Details – Please write to below email IDs

Tata Consulting Engineers <u>www.tce.co.in</u> Email: <u>tceconnect@tce.co.in</u>

THANK YOU