



Fuel Cell Bus Workshop Linde H2 Fueling

Diamond Bar, CA
September 17, 2013

Leading.



THE LINDE GROUP

Nitin Natesan

Linde North America, Hydrogen Fueling

Linde Covers The Entire Hydrogen Value Chain

Global presence in > 100 countries, 48.000 employees, € 12.8 billion sales



Large-Scale Production



Conventional
(e.g. SMR)



Green
(e.g. BTH)

On-site Supply & Storage



CGH2 storage



LH2 storage

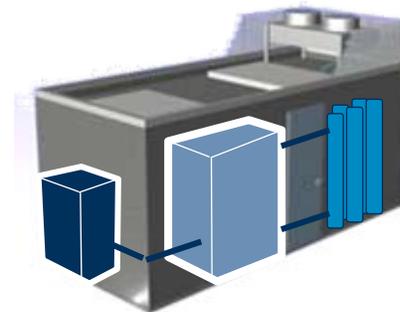


Onsite SMR



Onsite Electrolyzer

Compression/Transfer



Ionic compressor



Cryo pump

Dispenser



350 bar



700 bar

Hydrogen Fueling

Core Technologies & Product Lines



Description **Capacity¹** **Pressure** **Linde US Installations**

Dry Runner



Lubricant free piston compression
Flexible Design / Transportable

5 – 11 kg/hr

350 - 700 bar

AC Transit Emeryville

Ionic



Ionic liquid as piston for compression.
Near Isothermal Design

8 – 30 kg /hr

450 - 900 bar

BMW, Whole Foods, AC Transit, Coca Cola

Cryo Pump



Processes liquid hydrogen feed
High Throughput
Low losses

> 100 kg /hr

350 - 900 bar

Lawrence Livermore National Laboratory

Fueling Technology

¹ Single train, compressor system ISO-containers can accommodate two trains

Linde fuel cell bus fueling experience

~ 12,000 fuel cell bus fuelings to date



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Project / customer	Location	Refuelling capacity	Technology
CUTE project	Amsterdam	Up to 100 kg per day	Piston compressor
CUTE project	Porto	Up to 100 kg per day	Piston compressor
CUTE project	Barcelona	Up to 100 kg per day	Piston compressor
CUTE project	Perth	Up to 100 kg per day	Piston compressor
CUTE project	London	Up to 100 kg per day	Cryogenic pump
Shell / Tongji	Shanghai	56 kg per hour	Diaphragm compressor
CEP / Total	Berlin	Up to 140 kg per day	Ionic compression
Nuclear Research Inst.	Prague	30 kg per hour	Dry piston compressor
AC Transit	Emeryville	5 kg per minute	Ionic compressor
AC Transit	Oakland (3Q '11)	5 kg per minute	Ionic compressor
CEP / Vattenfall	Hamburg, Germany	70 kg per hour	Ionic compressor
CEP / Shell	Berlin, Germany	Up to 2400 kg per day	Cryo Pump
CHIC project	Milan, Italy	Up to 75 kg per hour	Ionic compressor
CHIC project	Bolzano, Italy	Up to 75 kg per hour	Ionic compressor

AC Transit Project Profile

Customer:

AC Transit, Emeryville, CA

Project Features:

- 12 fuel cell buses (350 bar) – in fueling times similar to diesel
- Public fueling (350/700 bar) per J2601 Category A
- Dual Hydrogen Supply – Liquid and On-Site Electrolysis
- Integrated Solar Cells to Supplement Power Consumption
- Linde Compression Technologies - 350 bar Ionic Compression and 700 bar Piston Compression
- Combined Car and Bus Fueling Station & Integration

Linde Scope of Supply & Service:

Major Equipment Design and Installation - limited site infrastructure

Service:

Majority of equipment owned by AC Transit. Operations and Maintenance agreement with Linde



Linde Plot Overview

AC Transit, Emeryville

External High Pressure Storage

IC50 Bus Compressor

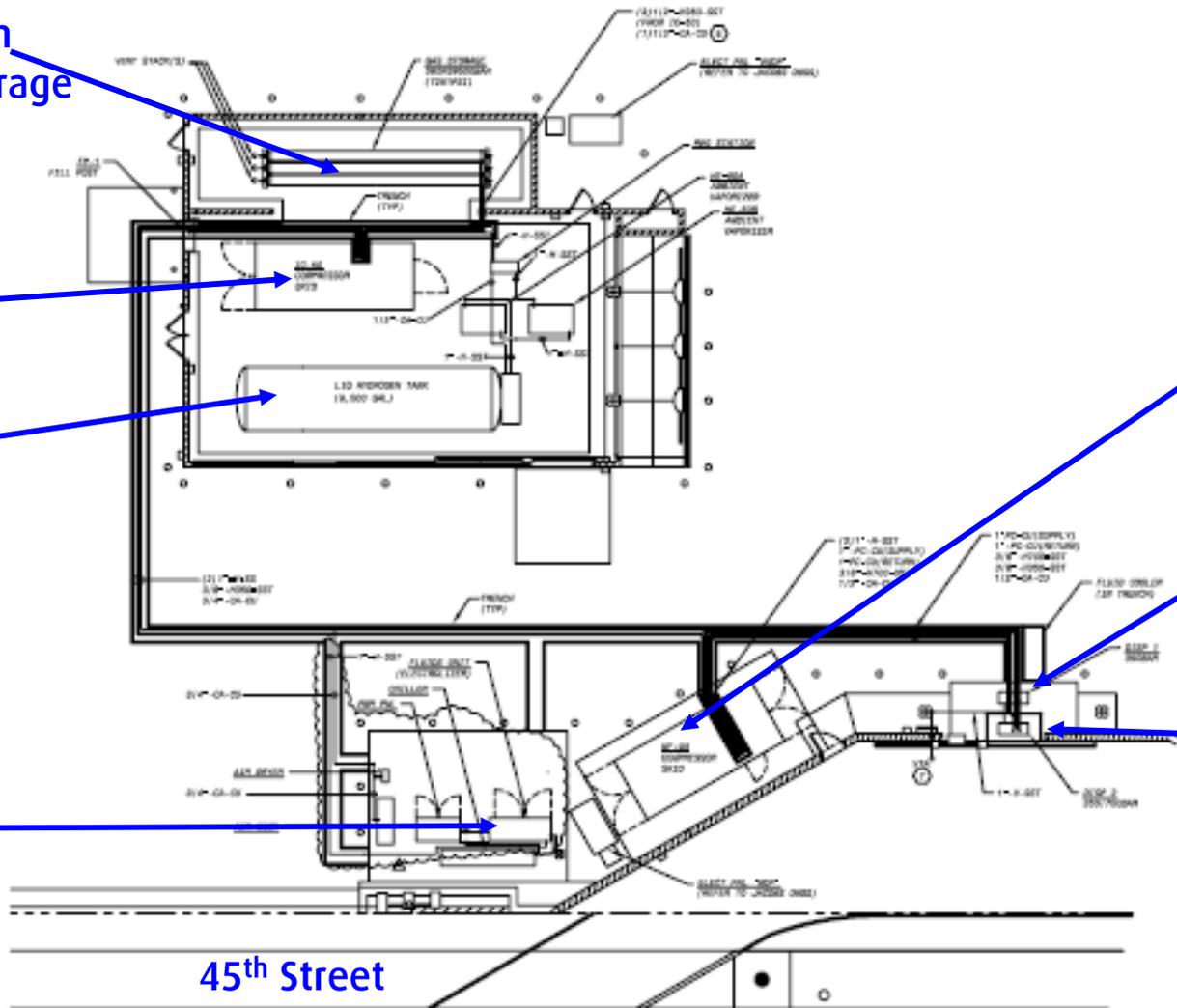
LH2 Tank

Proton Electrolyzer

MF90 Car Compressor

Bus Dispenser

Car Dispenser



45th Street

Site Photographs – H2 Equipment Yard Aerial

AC Transit, Emeryville



Site Photographs

Proton Electrolyzer - 65kg/day, PEM, Solar Power



Site Photographs

Over 3600 Fuel Cell Bus Fueling Events To Date (>52,000 kg)



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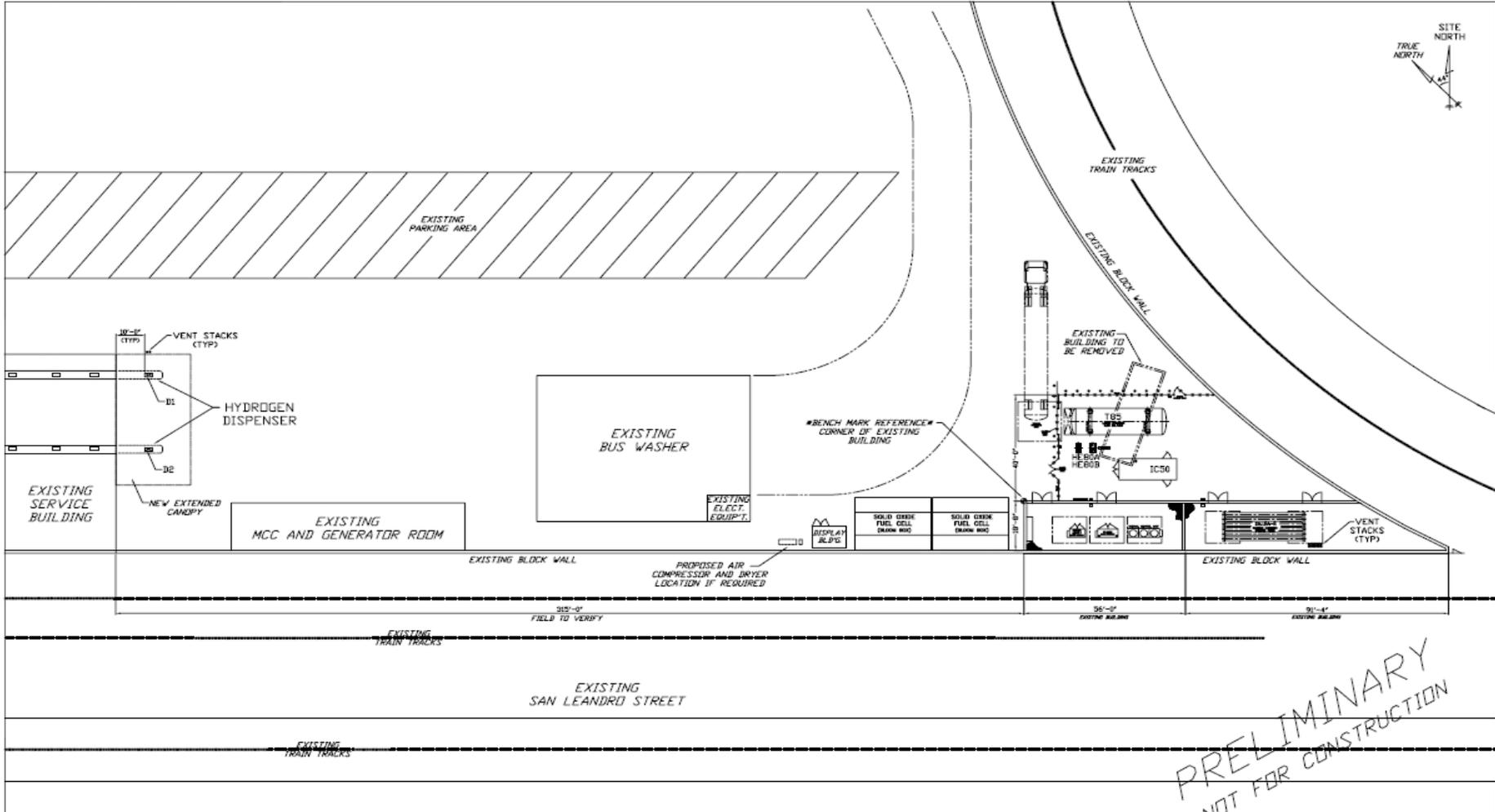


Site Photographs

Car fueling – Mercedes, Toyota, Nissan and GM Cars Fueled
3 Back to Back Fueling Events of Mercedes



AC Transit – Oakland (Emeryville Duplicate without Car Fueling) Q2 - 2014



PRELIMINARY
NOT FOR CONSTRUCTION

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STATUS	DATE	DESCRIPTION	BY	CHK	REVIEW	APPR	DATE	PROJECT NUMBER
ISSUE	15-APR-11	PRELIMINARY	AP					AC TRANSIT - OAKLAND-D4

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AC TRANSIT - OAKLAND-D4

HYDROGEN FUELING
FUELING @ 350 BAR(A)
PLOT PLAN

OAKLAND
SCALE: 1/16"=1'-0" ENG.
P-D-003-01 ISSUE 00A CA

Expansion Scenarios – FLT Fueling (45' x 45' Lot)

Original: 200 kg/day

Expanded: 600 kg/day

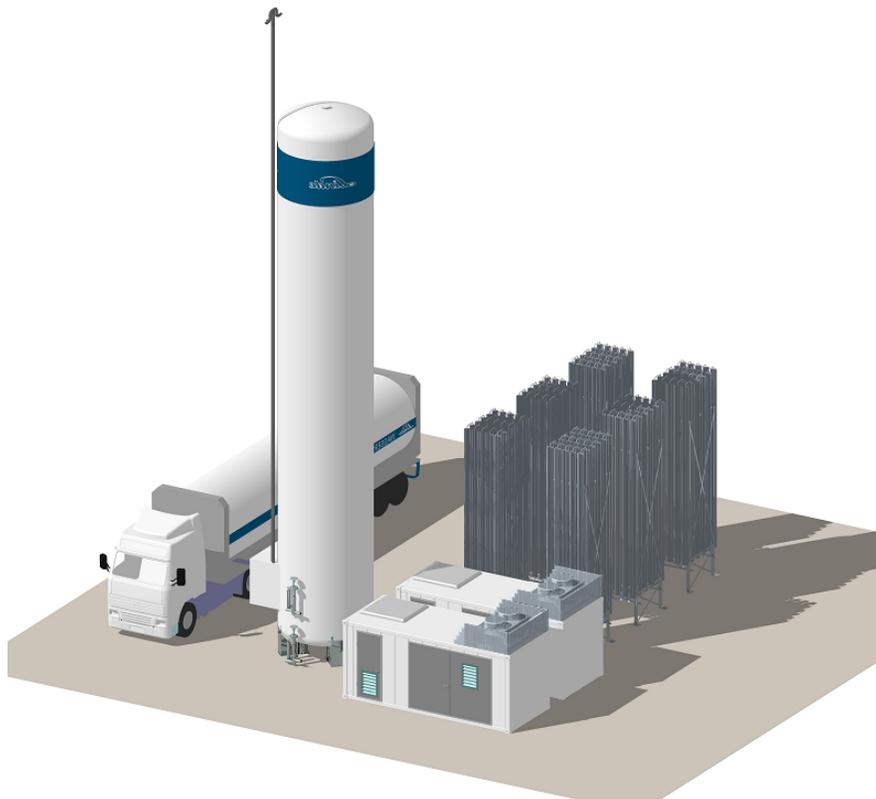


Lawrence Livermore National Laboratory – Cryogenic Liquid Pump Project (> 100 kg/hr @ 350 & 900 bar) 20' x 60'



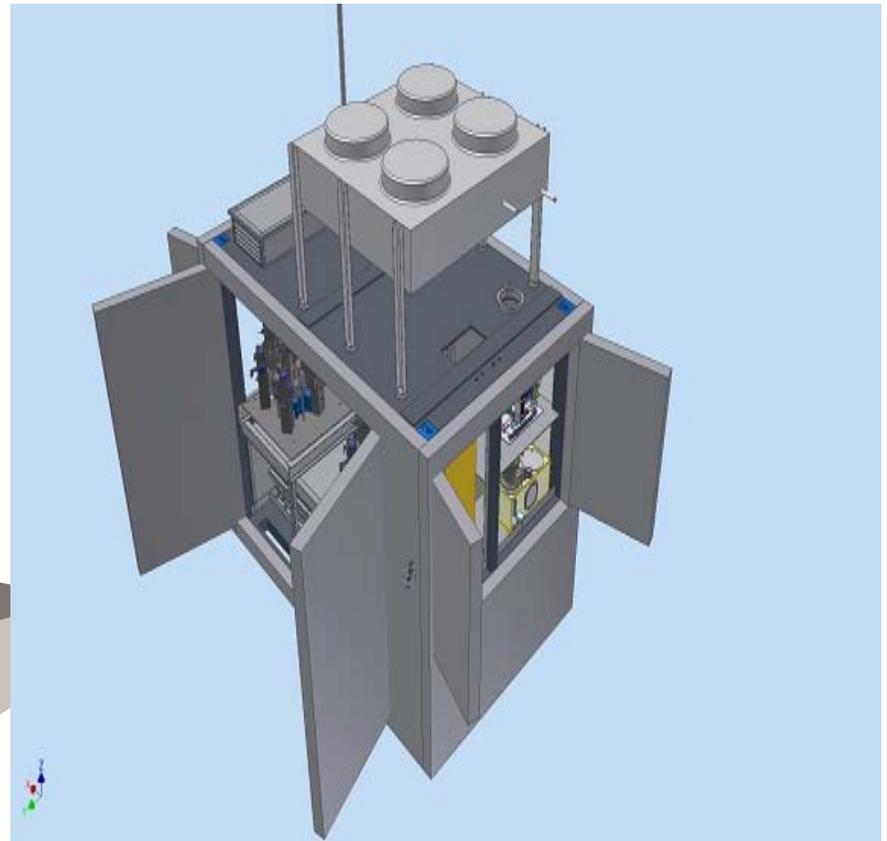
DUAL LIQUID PUMP SYSTEM

Conceptual – 4 pumps in 2 containers >400 kg/hr at 350 or 900 bar



DUAL IONIC COMPRESSOR SYSTEM

Conceptual - 2 Compressors per container up to 60kg/hr @ 900 bar



Cryogenic piston pump, Large scale system



Accessibility: Public/bus operator

Start of operation: 2011

Dispensing lines: 1 x 700 bar - FCEV
1 x 350 bar - FCEV
1 x 350 bar - Bus

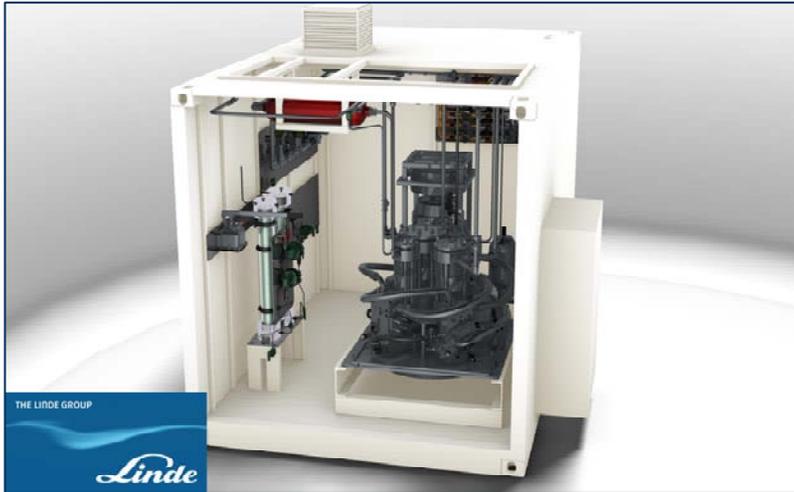
Technology: 2 x Cryopump (each pump 120 kg/h)

H2 source: LH2 storage tank

Customer: Shell



IIT Bolzano Station Under construction



Accessibility: Semi-public

Start of operation: Q2 2014

Dispensing line: 2 x 350 bar bus
1 x 700 bar car

Technology: Ionic Compression

H2 source: 3x electrolyzer and
back-up via GH2
trailer

Customer: IIT Bolzano, Southern
Tyrolia. Italy



- High performance technology options for the future expansion
 - Ionic compression 900 bar
 - Cryogenic piston pump
 - Customized engineering solution for application
- Experience
 - ~12,000 fuel cell bus fuelings globally
 - Over 80 hydrogen fueling stations to date globally
 - Leverage Linde operations personnel and technicians worldwide
 - Over 500,000 fueling events in US
 - Actively participate in CaFCP, FCHEA, SAE, CSA, NFPA, CHBC

Thank You For Your Attention

Leading.



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