Hydrogen Energy: Production, Storage, Transportation and Safety

Prof. Pratibha Sharma
Department of Energy Science and Engineering
Indian Institute of Technology, Bombay

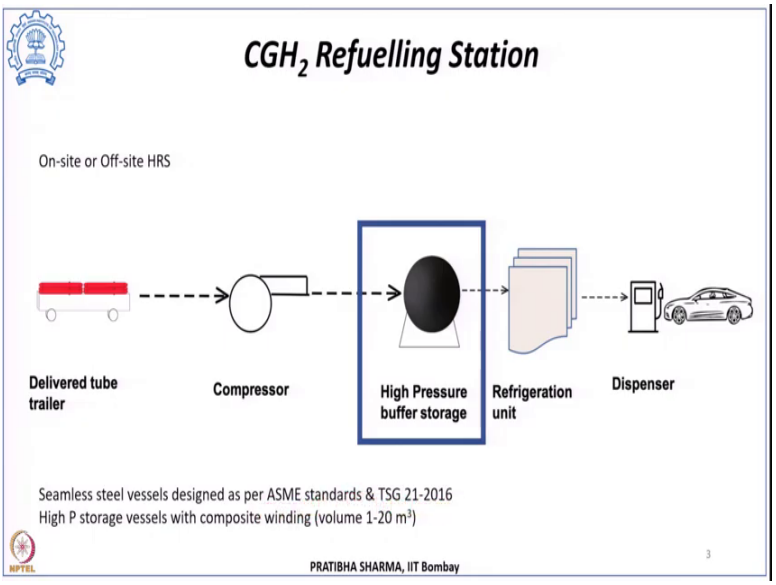
Lecture - 59
Hydrogen Refueling Stations

Hydrogen Refueling Station is a complex system and it consists of several components like, compressors, storage vessel, then there is a dispenser, high pressure filling lines, then there is a chiller or heat exchanger or the pre cooling unit. Now, these hydrogen refueling stations can be of two types, either it could be an onsite hydrogen refueling station where, in case when the hydrogen production place is far off from the hydrogen refueling station or if the hydrogen refueling station is not connected to the distribution terminal.

In that case, hydrogen is being produced onsite using any either a reformer or an electrolyzer. It is carried using transmission pipelines and distribution pipelines through the service pipelines to the hydrogen refuelling station or it can be an offsite hydrogen refueling station. Wherein the hydrogen which is being produced in a central production plant or in a semi central production plant, it is carried using tube trailers or insulated trucks onto the refueling station.

Now at the refueling station these can be these refueling station can be either compressed gaseous hydrogen refueling station or it could be liquid hydrogen refueling station. So, in this class we will learn about the different components which can which are there in the hydrogen refueling station and what is the mechanism of its operation in very brief.

(Refer Slide Time: 01:57)

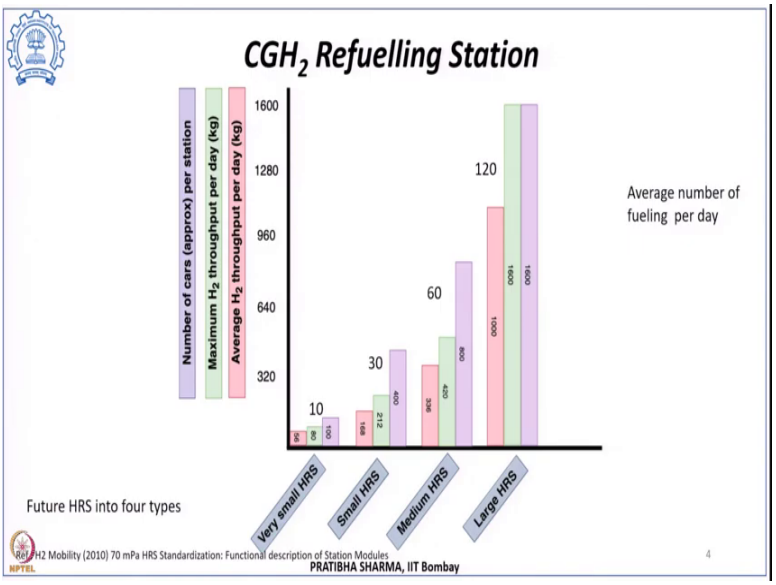


Now, in a typical compressed gas hydrogen refuelling station the hydrogen which is carried from the distribution terminal through delivery tube trailers this is at a certain pressure that we have seen in the last class. It is compressed using a compressor from the tube trailer pressure to the high pressure buffer storage pressure.

And before filling into the vehicle tank this has to be cooled to a certain temperature and finally, through a dispenser has to be filled into the onboard onto the car tank. Now, in among these there are several components as I mentioned now one of the important component of the compressed gas hydrogen refuelling station is the high pressure buffer storage. Now, this is important in the sense that determines the capacity of a hydrogen refuelling station.

Now, this can operate depending upon the application this can be either a high pressure storage facility, which could be made up of composite material that we have already seen in the previous classes either similar to type 3 or type 4 winding tanks. Then the volume could be typically 1 to 20 meter cube depending upon the size of the fuelling station or it could be a low pressure tank, which could be either a seamless steel vessel and all these have a standard like it has to be designed as per the ASME standard and TSG 21-2016.

(Refer Slide Time: 03:33)

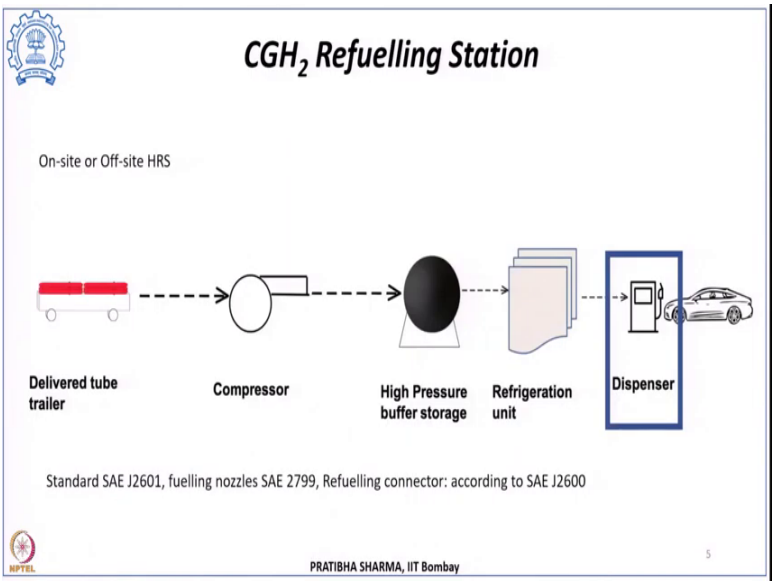


Now, depending upon what is the capacity of this buffer storage there can be different types of hydrogen refuelling station. Now the future hydrogen refuelling station has been categorized into either very small hydrogen refuelling station, small, medium or large hydrogen refuelling station. Depending upon what is the maximum hydrogen throughput per day in kgs, what is the average hydrogen throughput per day and the number of cars that arrive approximately per station?

Now, herein for a very small hydrogen refuelling station, one refuelling point is being considered similarly, for small refuelling station 1 fueling point, for medium 2 refuelling point and for large hydrogen refuelling station four refuelling points have been considered. Now, these are some of the numbers like, the average hydrogen throughput this is 56 kg per day for a very small refuelling station.

It is 168 kg for a smaller, 336 kg for a medium hydrogen refuelling station and 1000 kg for a large refuelling station. And typically the average number of fuelings per day for a very small hydrogen refuelling station is 10, for a small hydrogen refuelling station is 30, for a medium it is 60, and for a large hydrogen refuelling station is 120. There are several standards that teach to be followed for each of these type of refuelling station.

(Refer Slide Time: 04:54)

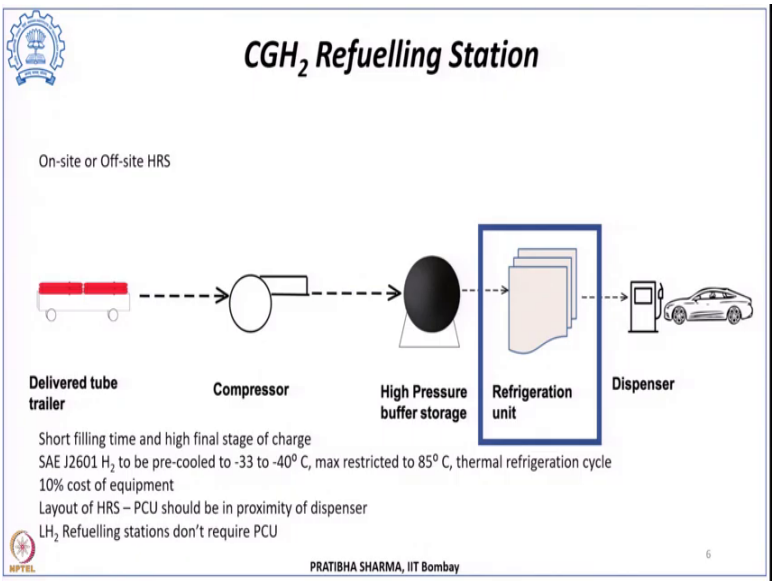


Now, the another major component of a compressed gas hydrogen refuelling station is the dispenser. Now this dispenser it again consists of several components. So, it has high pressure piping's, filling lines then it has a shutoff pneumatic valve then it has a supporting explosion proof solenoid valve. Then there are different monitor's temperature and pressure sensors, temperature and pressure regulators, then there are different control mechanism gas guns, chip controller complete control panel within the dispenser.

So, all these components these are housed into the dispenser. Now, they perform here multiple functions like they prevent from over pressurization. So, these components are integrated together in dispenser and they perform functions like prevention of over pressurization, ambient temperature compensation, it also prevents immediate like shutoffs in case of any emergency, hose break prevention then, it also provides a sort of sequential gas extraction.

So, as to fill into the vehicle tank. So, all the components all the functioning has to follow all the standards like, the typical standard followed is SAE J2601. The fueling nozzle has to follow SAE 2799 standard, refuelling connector according to SAE J2600 standard.

(Refer Slide Time: 06:34)



Now the, another important component which is in the compressed gas refuelling station is the refrigeration unit. Now, this is very important in the sense that we require a very short fueling time when a car arrives at a refuelling station we want that it should be fueled in a minimum time with a least waiting time and the filling should be at the maximum allowable.

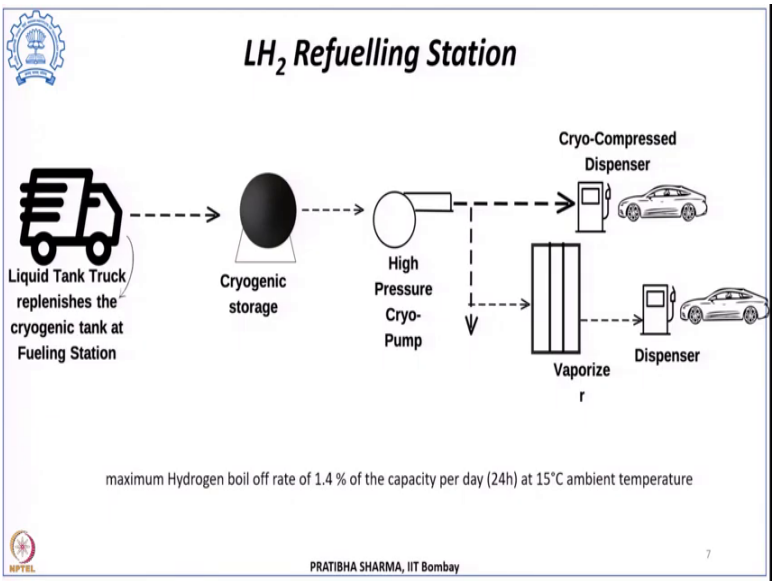
So, it should have a short filling time along with high final state of charge. Now, as per the SAE J2601 standard the hydrogen before filling should be pre-cooled to a temperature of minus 33 to minus 40 degree centigrade. In such a way this is required such that the maximum temperature during filling, which could be reached, is 85 degrees centigrade. So, that is the maximum restriction onto the achieved temperature during the filling process.

And this refrigeration is being achieved through thermal refrigeration cycle. So, there are components like there is a chiller, there is a heat exchanger and then there is an associated piping; when hydrogen is extracted from the high pressure buffer storage before it is being dispensed into the vehicle it has to go through chiller where, the coolant circulates through a heat exchanger extracts heat from the hydrogen and then returns back to the chiller.

In the whole process the temperature of hydrogen reduces in this particular range minus 33 to minus 40 degree centigrade. Now, this pre cooling unit is cost intensive. So, the total equipment cost is about 10 percent of the total cost of the entire equipments. And it is essential while designing the hydrogen refuelling station that this pre-cooling unit should be in close proximity to the dispenser. This is so, as to avoid the energy losses. However, this pre

cooling unit is not required if the filling station is a liquid hydrogen filling station with a cryo pump being used.

(Refer Slide Time: 08:56)

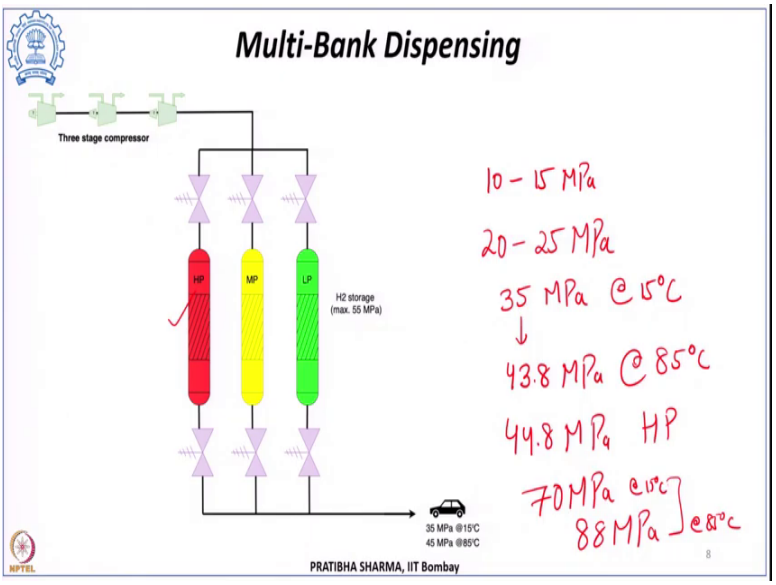


So, the other option could be a refuelling station, which operates on liquid hydrogen. Now, similar to that we have seen in the compressed gas hydrogen refuelling station the components involved here are. So, the hydrogen could be transported from the distribution terminal by a means of liquid hydrogen trucks and that is used to replenish the storage tank on site onto the refuelling station.

So, there is a cryogenic super insulated vessel storage that could be either underground or above the ground. And at the time of filling through a high pressure cryo pump it can be filled via dispenser into the car tank; either it could be a cryo compressed filling or it could be a compressed gas filling.

Now, for that the liquid hydrogen has to be evaporated converted into gaseous hydrogen and finally, through a dispenser filled onto the vehicle tank. So, the limitation that lies in this liquid hydrogen refuelling station is, that the maximum hydrogen boil off rate should be limited to 1.4 percent of the capacity per day in 24 hours and considering that the ambient temperature is at 15 degree centigrade.

(Refer Slide Time: 10:11)



So, this was about the major components of the compressed and liquid hydrogen refuelling station there are different mechanisms through, which this filling can be done and like one of the concept is a multi bank dispensing. Now, in multi bank dispensing there are multiple storage banks like, there are three storage bank in this figure like a low pressure bank, a medium pressure bank and a high pressure bank.

Now this does not mean that they will not go to the highest pressure; however, during the filling cycle all the three pressure banks they are filled to the same pressure level; however, while utilizing a pressure bank when the pressure drops in a particular vessel or a pressure storage bank then, still the advantage of this method is that can still be utilized to fill the car tank.

So, there are three steps in which the filling of the car tank takes place initially the hydrogen from a lower pressure bank flows into the onboard tank. So, usually the pressure filling with the low pressure bank is in the range of 10 to 15 MPa. So, with the low pressure the filling level is say 10 to 15 MPa. Now to fill the car tank to 15 MPa the pressure in the low pressure bank should be 16 MPa at least.

So, once the required pressure is achieved in the car tank the flow immediately switches automatically switches to the medium pressure bank, where the medium pressure bank fills the car tank to a pressure of 20 to 25 MPa this is considering that the capacity of the tank in

the car is for 35 MPa filling. And finally, once the achievable pressure with the medium pressure bank is achieved in that case the flow switches to the high pressure bank.

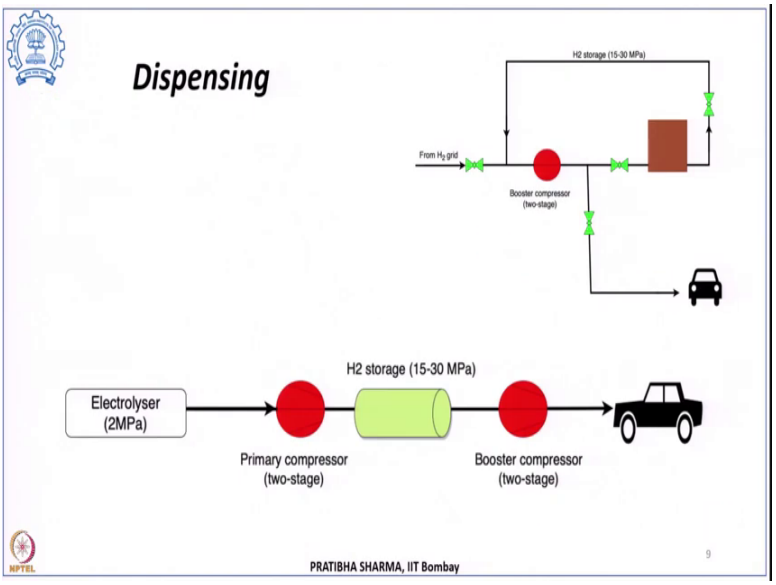
Now, this high pressure bank finally, it delivers a required pressure of say 35 MPa when the storage capacity of the tank is 35 MPa or the storage pressure allowable storage pressure is 35 MPa. Now, we need to remember that this 35 MPa maximum pressure in the car tank that is, considering that filling has been carried out at 15 degree centigrade.

However, we know that when we fill hydrogen the temperature increases. Now, once that temperature increases we have seen that the pre-cooling unit is present. So, as to restrict the maximum temperature to 85 degrees centigrade as per the standard; now once we once the filling is carried out in the car tank the maximum temperature that reaches is 85 degrees centigrade. Now at 85 degrees centigrade this 35 MPa corresponds to 43.8 MPa.

So; that means, when the temperature comes back to normal if we have filled at 35 MPa and the temperature reaches to 85 degree centigrade and when it comes back to normal then it will not be filled to the same level. So, over pressurization is required. So, that corresponds to filling at 85 degree centigrade to 43.8 MPa. Now, if the car tank pressure is 43.8 MPa; that means, if it has to be filled through the high pressure bank the high pressure bank should be at a pressure above 43.8 MPa. Usually it should be at 44.8 MPa. So, this is the high pressure bank pressure.

Now; that means, roughly it should be around 45 MPa at 85 degree centigrade. Now, this is when the car tank is meant for 35 MPa if; however, the car tank is meant to store at say 70 MPa then the high pressure bank should deliver at a pressure of 88 MPa at 85 degree centigrade and this is at the 15 degree centigrade. So, this is how the multibank dispensing works.

(Refer Slide Time: 14:43)



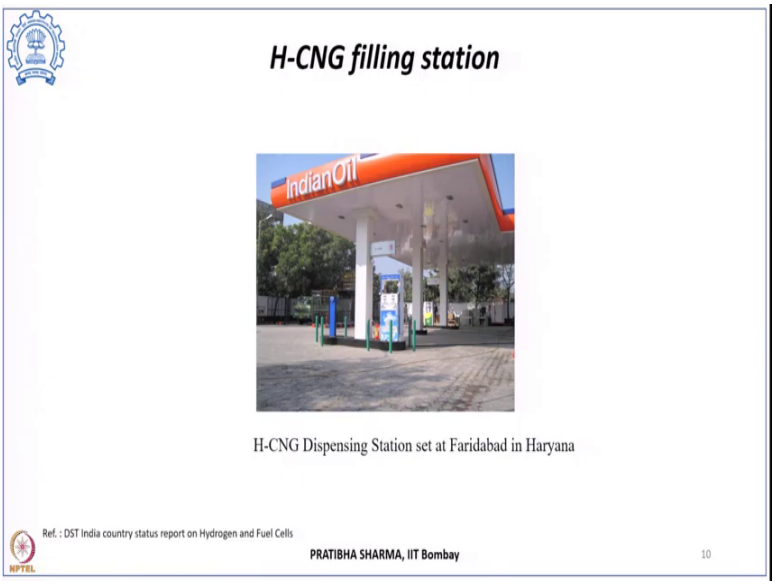
Now, the another possibility could be wherein when the hydrogen, which is let us say on site produced using an electrolyzer it is compressed and stored into hydrogen storage vessel, which is present at the hydrogen refuelling station and this is stored at a pressure between say 15 to 30 MPa that is, lower than the pressure that is desired for filling onto the car tank.

So, there is a primary compressor to raise the pressure from the production point electrolyzer, 2 MPa to say in between 15 to 30 MPa for storing into that storage vessel. And when required the pressure level is further increased to the filling level to the filling pressure whether depending upon whether it is a 35 MPa tank in the car or a 70 MPa tank. Accordingly, the second stage compressor, the booster compressor it increases the pressure to the filling level. And then it is filled through the dispenser.

Now, the another concept could be single compressor, a booster compressor is used to boost the pressure not only to fill to the required pressure level in the car tank, but it is also increasing the pressure from the production point or from the transmission terminal whatever pressure we have achieved this is used to increase the pressure and fill it into the storage vessel. So, both the same compressor it is used for filling into the car tank and also pressurizing to store into the hydrogen storage unit at say 15 to 30 MPa.

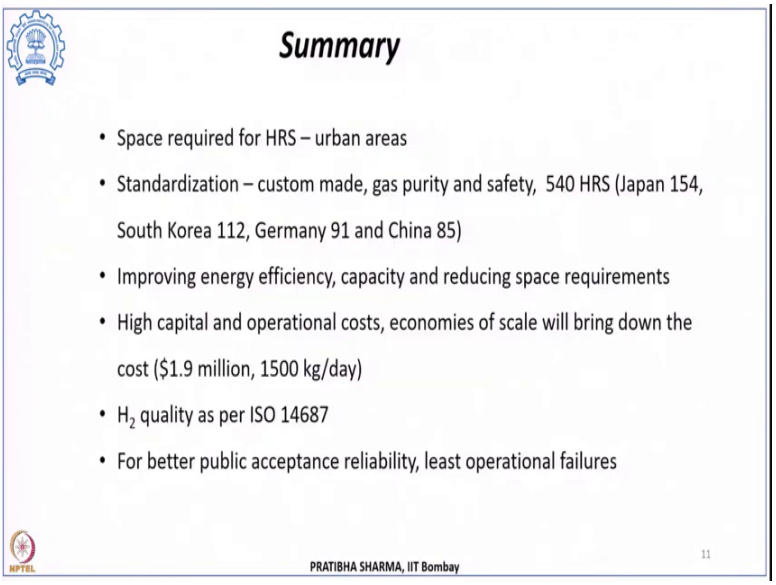
So, it does both the functions in that case. Now, this is the booster dispensing type of concept.

(Refer Slide Time: 16:46)



This is a typical picture of a hydrogen filling station it is a hydrogen CNG filling station a blend, which is at Faridabad in Haryana and this is by IOCL and the references from the country status report.

(Refer Slide Time: 17:06)



To summarize this portion to have a hydrogen refuelling station, it requires certain space and in the urban areas to have that space is very crucial. So, it will be the requirement will be that the footprint area of such hydrogen refuelling station should be as low as possible.

Currently if we see the status there are about 540 hydrogen refuelling stations, among them Japan has the highest one with 154 filling stations, South Korea 112, Germany 91 and China 85 filling stations. Now, the numbers may slightly vary depending upon the references most of these like since the number of refuelling station is still less they are custom made. So, there is a requirement of standardization across the globe it is in terms of safety, in terms of gas purity and other requirements.

It is also essential that the energy efficiency capacity should improve and the space requirement should reduce or the footprint area should reduce. Now currently if we see there is a high capital and operational cost involved with setting up these hydrogen refuelling stations like, typically the cost it is mentioned is like 1.9 million dollars and for a hydrogen refuelling station having a capacity of 1500 kg per day. But definitely with time the economies of scale when the numbers will grow this cost will come down.

The quality which is dispensed at these dispensing stations should be as per the standards like, ISO 14687 and it is very much essential that the public acceptance is required and for that reliability is going to play a very dominating role. In the sense that the down times of such hydrogen refuelling station should be as low as possible. Because a single trip being not able to fill fuel that may result into lot of annoying into the customer at the same time the acceptability will reduce.

Now currently since we know that the number of hydrogen refuelling stations is very less. So, in that case the trained manpower to do the maintenance at the same time the availability of the components in case of downtime is very limited. So, as such it is required that this non operational periods should be as low as possible. So, as to improve the public acceptance and that can also be taken care of by mobile hydrogen refuelling stations.

Thank you.