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Automatic Refuel Coupling for Liquid Hydrogen Tank Trailers

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1 Distribution of Hydrogen State of Technology

Production of hydrogen is operated either directly on-site by consumers or by suppliers of industrial gases. To optimize the transportation it is required to compress or liquefy the hydrogen.

For the distribution of liquid hydrogen in medium quantities to the consumers often special tank trailers are used.

2 Current Solution in LH_2 Trailers

Normally the transfer of liquid hydrogen from a trailer to the customer tank is carried out by a manually operated and open unprotected coupling.

Such couplings are of the Johnston type principle. Design characteristics are several coaxial pipes in defined cryogenic lengths resulting in a male and female part with a vacuum insulation and a pressure-tight connection between.

However these devices are not ideal for the handling of liquid hydrogen. It is caused particularly by its limitation only to connect and disconnect the coupling in a pressureless and medium-free state. The procedure for a pressureless coupling and uncoupling with its subsequent operations (cooling, purging, warming and venting the line) requires significantly more time. This adds to the overall duration of the transfer operation from the distributors tank to the trailer and from the trailer to the customer tank.

For instance the procedure of venting the line takes about 1 to 2 hours extra time. Moreover a large quantity of valuable hydrogen is lost during these operations.

3 Approaches and Requirements of the New Design

First solutions of semi-automatic Johnston couplings are known in WEKA's standard programme since the 80th. But for application in LH_2 tank trailers several more requirements have to consider.

Most important specifications are:

- L/GH_2; 20…323 K
- Design pressure 6 barg = 0.6 MPa
- Manually connected; automatically coupling and decoupling
- Inhibit leakage of L/GH_2
- Avoid entrapped air
- Prevent impurities of medium
- Minimize heat load
- Shortest possible cryogenic length for compact design

- Disconnect without warming and venting procedure
- Protect against faulty operation
- Leakage detection

4 Development of Prototypes

In further development and as a part of several customer projects various coupling prototypes have been developed and optimized.

WEKA's technical solution allows an easy connecting and locking by hand as well as self-acting coupling and decoupling action. The automatic and compact coupling is based on the Johnston principle it is however specially designed for the use with liquid hydrogen.

So the function principle has been changed to avoid the necessity of the additional cooling and venting procedure.

In a first step the male and female part are docked and secured hermetically tight.

In the second step an actuated insert is automatically pushed in or retracted after the filling.

Main components and features of the new coupling design are:

- Pneumatic actuated ball valve on female part of the coupling opening to let pass the insert and closing just before the coupling will be disconnected and so to keep GH_2 inside.
- Shut-off valve integrated in the female part; it opens and closes only if the insert is in service position.
- Guiding and fixation unit to support easy handling and safety aspects.
- Pneumatic linear actuators for automatically operated insert.
- Control unit to assure correct activation of actuators and prevent faulty operation.
- Leak gas return to limit pressure in GH_2 filled volumes and recirculation into medium pipe.
- Connections to test tank and LH_2 feed tank.

Special focus was put in to leak tightness, prevention of impurities and avoidance of wrong handling. Therefore the coupling is designed with a double seal to medium and to ambient with O-rings, spring energized plastic seal plus metallic bellow.

The ball valve and pneumatic linear actuators are operated with a working pressure of 6 barg…10 barg.

Last but not least the optimal cryogenic length could be found with these prototypes.

5 Prototype successfully tested in LH_2 laboratory

The prototypes have been successfully tested in a specialised laboratory at customer site with LH_2 at cryogenic conditions. In result the hydrogen transfer has shown positive performance, no leakage could found and no unacceptable heat load was observed.

Tests particularly have covered:

- Cycles of coupling and uncoupling
- LH_2 endurance test
- Leakage- and functional tests

6 Further Development and Outlook

A follow-up project has been started for a coupling in DN25/PN12 however it is scalable up to DN50.

The challenge here is the development of a robust coupling system with a large nominal size of flow nevertheless still light enough to be operated by one man.

So the weight for the male part has to be less than 7.5 kg!

Several approaches to meet these requirements are pursued:

- Optimisation or substitution of metallic bellow, quick-acting closure, etc.
- Weight reduction, cost minimising
- Serial production
- …

Continuation of the development is in progress with several functional tests. Pre-serial models for the field testing are planned in 2010/11.

7 Conclusion

- Automatic fuel coupling reduces duration of LH_2 filling significantly by a higher safety level.
- Prototype with DN15 successfully tested.
- Coupling and decoupling is possible with medium inside (GH_2).
- Nominal sizes up to DN50 = NPS 2” and nominal pressure up to 12 bar feasible.
- Optimisation relating to handling, dimensions and weight still required.