

BBR LNG/LPG PT Technology

Project References 1980 – 2016

Tailored, Certified & Reliable





BBR A Global Network of Experts www.bbrnetwork.com

The BBR Network is recognized as the leading group of specialized engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 70 years later, in that same ethos and enterprising style.

From its Technical Headquarters and Business Development Centre in Switzerland, the BBR Network reaches out around the globe and has at its disposal some of the most talented engineers and technicians, as well as the very latest internationally approved technology.

THE GLOBAL BBR NETWORK

Within the Global BBR Network, established traditions and strong local roots are combined with the latest thinking and leading edge technology. BBR grants each local BBR Network Member access to the latest technical knowledge and resources – and facilitates the exchange of information on a broad scale and within international partnering alliances. Such global alliances and co-operations create local competitive advantages in dealing with, for example, efficient tendering, availability of specialists and specialized equipment or transfer of technical know-how.

ACTIVITIES OF THE NETWORK

All BBR Network Members are well-respected within their local business communities and have built strong connections in their respective regions. They are all structured differently to suit the local market and offer a variety of construction services, in addition to the traditional core business of post-tensioning.

BBR TECHNOLOGIES & BRANDS

BBR technologies have been applied to a vast array of different structures – such as bridges, buildings, cryogenic LNG tanks, dams, marine structures, nuclear power stations, retaining walls, tanks, silos, towers, tunnels, wastewater treatment plants, water reservoirs and wind farms. The BBR™ brands and trademarks – CONA®, BBRV®, HiAm®, HiEx, DINA®, SWIF®, BBR E-Trace and CONNÆCT® – are recognized worldwide.

The BBR Network has a track record of excellence and innovative approaches – with thousands of structures built using BBR technologies. While BBR's history goes back over 70 years, the BBR Network is focused on constructing the future – with professionalism, innovation and the very latest technology.

BBR VT International Ltd is the Technical Headquarters and Business Development Centre of the BBR Network located in Switzerland. The shareholders of BBR VT International Ltd are: BBR Holding Ltd (Switzerland), a subsidiary of the Tectus Group (Switzerland); KB Spennteknikk AS (Norway), BBR Polska z o.o. (Poland) and KB Vorspann-Technik GmbH (Germany) – all three are members of KB Group (Norway).

Innovation Excellence Experience

BBR has over 70 years experience in the design and application of post-tensioning products. For over 30 of those years, clients have repeatedly trusted BBR to deliver within the stringent requirements and extreme conditions of the LNG/LPG industry.

During this time BBR has been involved in over 4.5 million cubic meters of post-tensioned LNG/LPG storage amounting to +60 tanks in 10 different countries.

Our Swiss roots are deeply embedded in technological development and, through the years, our engineers have constantly strived to produce the most advanced products and technology.

Today, this combines with a strong international network – the BBR Network of Experts – who first listen, then advise and deliver best-in-class solutions to customers around the globe.

Front cover: LNG Tanks in Barcelona, Spain

#25



2001 – ADNOC Barouge LNG Tank, United Arab Emirates

#29



2006 – Darwin LNG, Australia

#30



2007 – South Hook LNG Tank, United Kingdom

#38



2008 – 4th LNG Tank Cartagena, Spain

#50



2012 – Ruwais Train LPG Storage, Abu Dhabi

Tailored

LNG is a natural gas that has been condensed to a liquid for ease of storage and transport. The phase change is achieved by cooling the gas to below $-162\text{ }^{\circ}\text{C}$, below the gas's boiling point. Under these conditions, minimal permeability and structural resilience are critical; which makes post-tensioned concrete tanks ideally suited as a structural system and 'secondary containment' skin.



Post-tensioning increases structural resilience while allowing reduced wall thickness, and reducing crack widths. Minimal permeability and high levels of corrosion protection are also required for all LNG/LPG structures; the post-tensioning system must therefore be designed and installed under strict quality controls, with materials and processes meeting specific certification and performance requirements.

BBR is used to operating in such environments with its long history in the Nuclear and Oil & Gas industries, where unique and tailored solutions are required to meet strict client, regulatory and construction demands.

Unique

Design and construction of each LNG/LPG tank is unique, but large above ground storage facilities almost exclusively use post-tensioned concrete as the basis of their structures. The post-tensioning systems are generally run both horizontally and vertically to meet the requirements of the design.

Construction methodologies play a decisive role in the success of an LNG/LPG tank project. Processes such as slip forming are specialised, but have significant benefits. Climbing in-situ concrete formwork integrated with scaffolding can be used to save construction time and cost as well as improving the safety and quality of the workers. BBR has streamlined its supply and installation activities to meet the specific requirements of such systems, to the benefit of many satisfied clients.

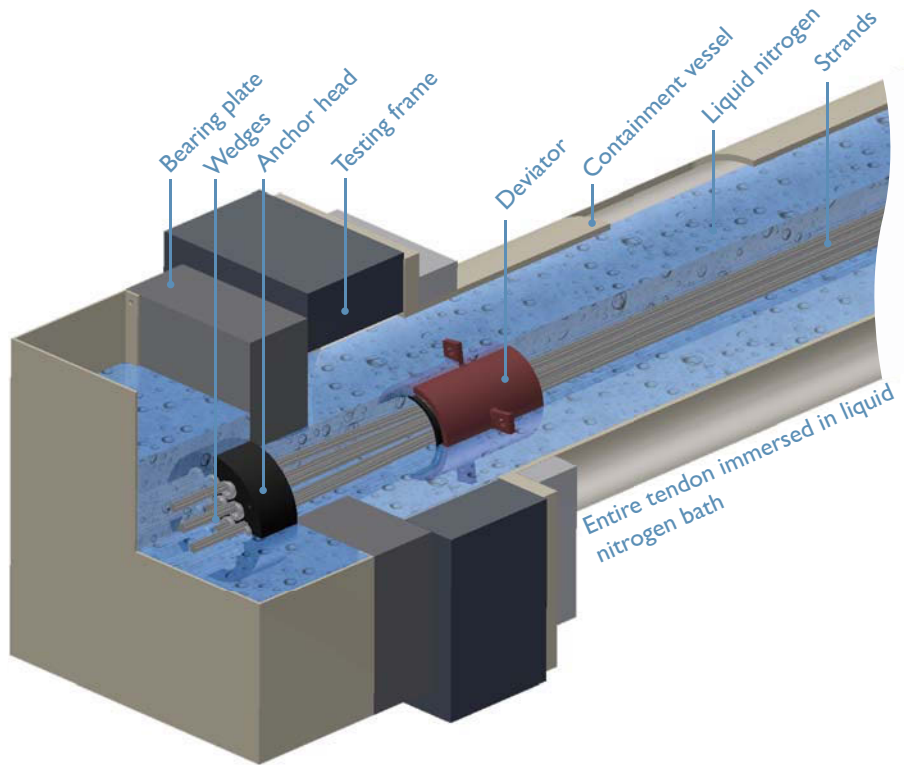


Certified

The European Organisation for Technical Approvals has set the benchmark for post-tensioning products operating in cryogenic conditions. As expected, BBR has met and exceeded every requirement.



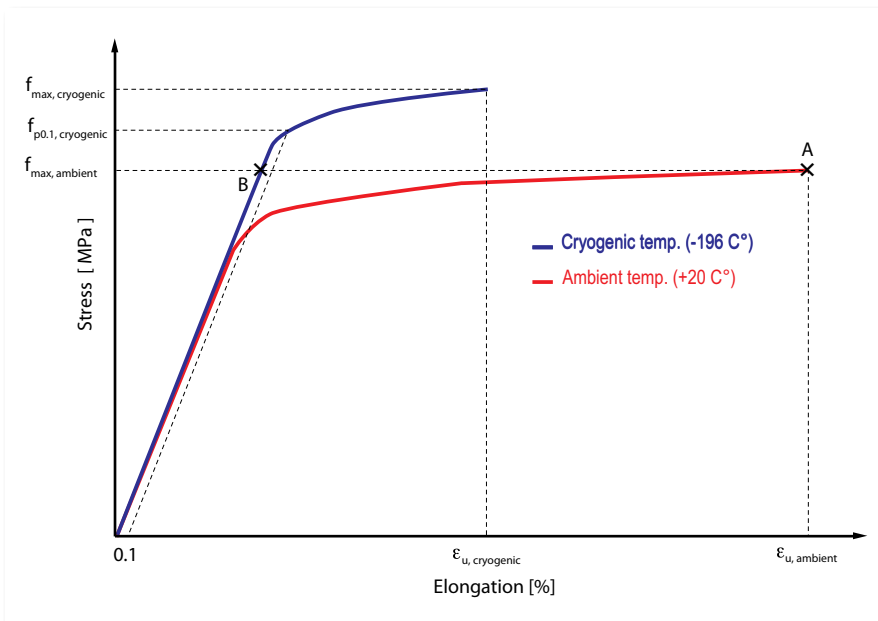
The Guideline for European Technical Approval, ETAG 013, outlines supplementary requirements which apply to PT systems for certain optional use categories, for instance in cryogenic applications. The cryogenic test setup with only one anchorage cooled down to the cryogenic temperature is commonly used to verify the performance of PT systems for cryogenic applications. However, this setup cannot examine the ductility of post-tensioning systems under cryogenic conditions. When only one anchorage is immersed into a liquid nitrogen bath, the tensile elements (strands) at both ends of the test specimen will be at two different thermal conditions. Part of the tendon near the immersed anchorage is subjected to the cryogenic temperature (-196 °C) and the rest of the tendon, which is fairly far from the cooling zone, is almost under ambient temperature (+20 °C). As known, prestressing steel experiences strengthening behavior when subjected to cryogenic temperature (see graph).



Thereby, the ultimate failure is always occurring at the tendon side under ambient temperature (see point A on graph), while at this load level the tendon part, which is immersed into the liquid nitrogen bath,

is still in the linear elastic zone (see point B). This means that the obtained ultimate failure force ($f_{max,ambient}$) is never reaching the yield point of the strand subjected to the cryogenic temperature ($f_{p0.1,cryogenic}$). The

outcome of this test setup does not verify the ductile performance of a PT system under cryogenic conditions. The BBR R&D department has carried out static testing of single and multi strand tendons in which the entire tendon, including both anchorages, is completely subjected to cryogenic conditions. BBR has further carried out a load transfer test under full cryogenic conditions. These tests are able to examine the ductility and load transfer efficiency of the system under these extreme conditions. The successful test results verify the ductility performance of the BBR VT CONA CMI post-tensioning system with normal grade anti-bursting reinforcement and prove that it is in full compliance with the ETAG 013 testing regime under both temporary and permanent cryogenic conditions without any need of using costly low temperature grade reinforcement and thus bringing significant material cost saving.



Reliable

Testing and development of BBR's product range is not the end of the story, a huge amount of resource goes into developing our people too.

A culture of continuous education within the BBR Network ensures high quality execution of all of our projects at every level. Our personnel have access to a huge depth of knowledge throughout the BBR Network, where practical and theoretical training courses are run throughout the world. At the end of each training course the attendees undergo an examination which is fully documented.



Solid

The capability of personnel is always important to the success of a post-tensioning project, but it is critical in the world of natural gas. Grouting is a process which is synonymous with internal post-tensioning and the quality of the end product is dependent on the skills and attention to detail of the applicators and technicians.

BBR's thixotropic grout mixtures are homogeneous mixtures of cement, water and admixtures. The mixtures and procedures used by all BBR PT Specialists fulfil the latest European Standards and are certified by an Independent Notified Body.

To guarantee the highest level of quality, BBR Network Members employ qualified and trained personnel in grouting. These expertise, coupled with leading equipment and the best materials leads to over 70 years of successful projects, as well as a huge bank of knowledge throughout the BBR Network.



CONA CMI for Cryogenic Applications

Development and certification is a day to day activity at BBR which goes hand in hand with a culture of innovation through continuous improvement of our products, systems and quality assurance.

Design and construction of large LNG/LPG tanks which are often near 90m in diameter and 50m in height involves significant design loads and often congested and unique detailing. The CONA CMI system has been continuously improved over the last years to meet such requirements, which is why it is the best choice for LNG/LPG projects. The unique BBR VT CONA CMI post-tensioning kit is a multi strand system with sizes available from 1 to 73 seven-wire pre-stressing strands.

End anchorage of the tendons is available as either a standard square bearing plate, the CONA CMI SP anchorage, or via the proprietary CONA CMI BT Bearing Trumplate. The CONA CMI BT anchorage

is available for sizes from 2 to 73 strands; it makes use of a three plane load transfer, which significantly reduces the peak bursting stresses, allowing for reduced tendon centre spacing and concrete edge distance as well as very low minimum concrete strengths at transfer.

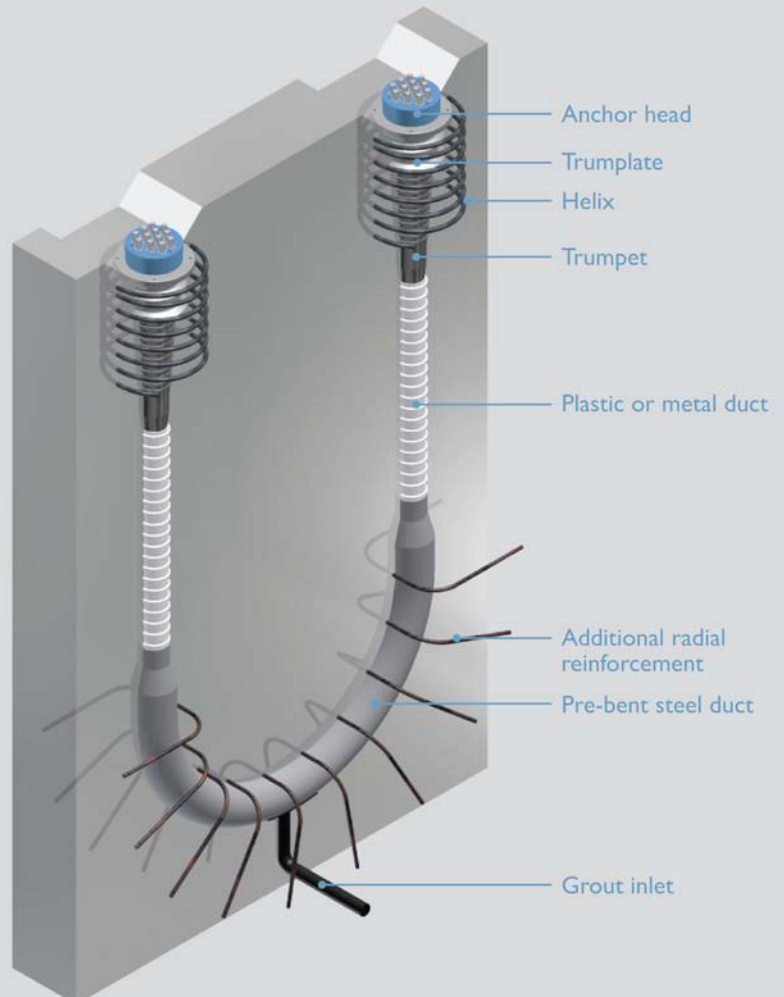
Vertical post-tensioning can be achieved through single tendons starting at the top of the tank and terminating in a socket at the base, or more commonly through the use of the BBR Loop Tendon detail.

BBR Loop Tendons have been developed for use in the LNG industry as an alternative to straight tendons as a result of experience from a number of projects where reinforcing congestion was a challenge.



BBR Loop Tendon PT Technology

Loop tendons are often used when there is no access to the dead end – for example for vertical post-tensioning in tanks and silos. In this scenario, the straight part of the tendon is inside the concrete wall and the loop is in the base of the tank. Whilst termination of PT strands at the base of a tank is not impossible, the reinforcing steel is usually already congested in this area and therefore adding a PT strand termination here can be problematic. Use of the BBR Loop Tendon system reduces congestion at the base of the tank and allows anchorage and stressing detailing to be minimized to the top of the tank. Minimum radii of curvatures of up to 0.7m are achievable, which is considerably less than the minimum bending radius of a normal prestressing strand. Due to the reduced radius of curvature, the contact pressure between the strands and the duct becomes very high, $p_{R,max} > 800$ kN/m. For the straight part of the tendon, corrugated steel or plastic ducts can be used, whereas a smooth steel duct is selected for the curved portion in order to dissipate the high contact pressures. For ease of installation, the degree of filling chosen for the curved part of the tendon should be very low. Please contact your nearest BBR representative to find out more.



#	Year	Name	Region	Capacity [m ³]	Tank Dia. [m]	Tank Height [m]
61	2016	Ethane Tank, Stenungsund	Europe	50,000	59	26
60	2016	LNG Tank Pori	Europe	30,000	42	35
59	2014	Rafnes Ethane Tank	Europe	30,000	45	32
58	2013	Barouge 3 - Ethylene Storage Tank 1	Middle East	21,000	34	30
57	2013	Ruwais Refinery Expansion Tank 3	Middle East	50,000	52	32
56	2013	Ruwais Refinery Expansion Tank 2	Middle East	50,000	52	32
55	2013	Ruwais Refinery Expansion Tank 1	Middle East	50,000	52	32
54	2012	LNG Tanks Gijon Tank 2	Europe	150,000	80	40
53	2012	LNG Tanks Gijon Tank 1	Europe	150,000	80	40
52	2012	Ruwais Train LPG Storage Tank 6	Middle East	75,000	67	36
51	2012	Ruwais Train LPG Storage Tank 5	Middle East	75,000	67	36
50	2012	Ruwais Train LPG Storage Tank 4	Middle East	75,000	67	36
49	2012	Ruwais Train LPG Storage Tank 3	Middle East	75,000	67	36
48	2012	Ruwais Train LPG Storage Tank 2	Middle East	75,000	67	36
47	2012	Ruwais Train LPG Storage Tank 1	Middle East	75,000	67	36
46	2011	Tank INEOS	Europe	57,000	49	43
45	2010	LNG Tank Risavika	Europe	30,000	49	29
44	2010	LNG Tanks in Barcelona Tank 8	Europe	150,000	82	50
43	2010	LNG Tanks in Barcelona Tank 7	Europe	150,000	82	50
42	2009	Barouge 2, Propylene Storage Tank	Middle East	23,000	38	32
41	2009	South Hook LNG Tank 5	Europe	155,000	92	35
40	2009	South Hook LNG Tank 4	Europe	155,000	92	35
39	2009	South Hook LNG Tank 3	Europe	155,000	92	35
38	2008	LNG Tank Cartagena	Europe	150,000	78	40
37	2008	Gasco LPG Tank 4	Middle East	96,000	63	34
36	2008	Gasco LPG Tank 3	Middle East	96,000	63	34
35	2008	Gasco LPG Tank 2	Middle East	96,000	63	34
34	2008	Gasco LPG Tank 1	Middle East	96,000	63	34
33	2007	Adriatic LNG Terminal Tank 2	Europe	125,000	88	47
32	2007	Adriatic LNG Terminal Tank 1	Europe	125,000	88	47
31	2007	South Hook LNG Tank 2	Europe	155,000	92	35

BBR Network Project References

#	Year	Name	Region	Capacity [m ³]	Tank Dia. [m]	Tank Height [m]
30	2007	South Hook LNG Tank I	Europe	155,000	92	35
29	2006	Darwin LNG	Pacific	188,000	92	35
28	2006	LNG Tanks in Barcelona Tank 6	Europe	150,000	82	50
27	2004	LNG Tanks in Barcelona Tank 5	Europe	150,000	82	50
26	2001	ADNOC Barouge LNG Tank 2	Middle East	29,000	37	27
25	2001	ADNOC Barouge LNG Tank I	Middle East	29,000	37	27
24	1997	Shell Tank T-0208	Europe	10,000	25	31
23	1996	North West Shelf Gas Project Tank 2	Pacific	81,000	60	31
22	1995	North West Shelf Gas Project Tank I	Pacific	65,000	53	32
21	1990	Arco Butane Storage Tank	Europe	62,000	50	45
20	1990	Low Temperature Tank 6 Kaarstoe	Europe	8,000	25	30
19	1990	Low Temperature Tank 5 Kaarstoe	Europe	8,000	25	30
18	1989	Du Pont Tank 2	Europe	5,500	20	25
17	1989	Du Pont Tank I	Europe	5,500	20	25
16	1987	Kwinana LPG Tank 3	Pacific	26,000	35	30
15	1987	Kwinana LPG Tank 2	Pacific	26,000	35	30
14	1986	Kwinana LPG Tank I	Pacific	26,000	35	30
13	1986	Du Pont Tank I	Europe	5,500	20	25
12	1984	Low Temperature Tank 4 Kaarstoe	Europe	20,000	39	30
11	1984	Low Temperature Tank 3 Kaarstoe	Europe	20,000	39	30
10	1984	Low Temperature Tank 2 Kaarstoe	Europe	20,000	39	30
9	1984	Low Temperature Tank I Kaarstoe	Europe	20,000	39	30
8	1982	Oxirane Tank 2	Europe	10,500	25	30
7	1982	Oxirane Tank I	Europe	10,500	25	30
6	1982	Botany Bay LPG Tank 2	Pacific	19,000	34	24
5	1982	Botany Bay LPG Tank I	Pacific	19,000	34	24
4	1981	Eurogas Terminal Tank 2	Europe	62,000	50	45
3	1981	Eurogas Terminal Tank I	Europe	62,000	50	45
2	1981	Dow Chemical Tank 2	Europe	62,000	50	45
1	1981	Dow Chemical Tank I	Europe	62,000	50	45

Our commitment



Having reached this page, you can certainly be in no doubt as to our commitment to the finest technology and our enthusiasm for delivering our projects.

Our seven decades of experience have resulted in BBR Technology being applied to countless LNG/LPG tanks and, in the process, we have continued to refine and enhance our range.

Technology does not however develop itself – through the years we have been fortunate enough to have attracted some of the best engineers in the business. It is their dedication which has maintained the BBR reputation – and continues to do so today.


Our well established worldwide network is supported in the development of LNG/LPG tanks and structures who will help to specify and procure the systems required. So, local knowledge synchronises with international know-how to realise projects – some large, some smaller; but always technically excellent and fit for purpose!





“Innovation distinguishes between a leader and a follower.”

Steve Jobs
Co-founder & CEO of Apple
1955 – 2011



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