BBR Nuclear Tendons

Project References

Powerful and trusted technology

BBR A Global Network of Experts
www.bbrnetwork.com

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 60 years later, in that same ethos and enterprising style.
From technical headquarters 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

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, DINA, SWIF, BBR E-Trace and CONNAECT – 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 60 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 Sp. z o.o. (Poland) and VORSPANN-TECHNIK GmbH & Co. KG (Austria / Germany), all members of the KB Group (Norway); BBR Pretensados y Técnicas Especiales, S.L. (Spain), a member of the FCC Group (Spain).

Innovation
Excellence
Experience

BBR has over 60 years' experience in the design and application of post-tensioning products. It will come as no surprise that we tested our first high capacity tendons for nuclear power stations as early as the 1960s.

Since then, the BBR Network has applied this leading edge technology to 65 nuclear facilities in many countries.

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

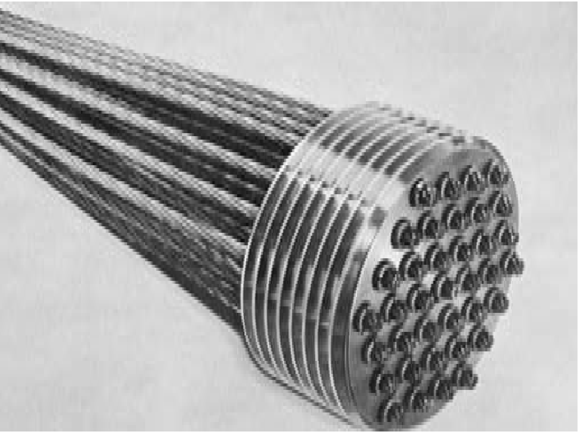
Today, this combines with a strong international network – the BBR Network of Experts – who first listen, then advise and deliver best-in-class solutions to customers around the globe.

Cover image: Courtesy of Axpo Holding AG

Pioneering BBR spirit

BBR engineers were pioneers in the truest sense of the word when it came to developing high capacity tendons for nuclear applications. As early as the 1960s, they tested the first generation of large tendons for nuclear power plants – BBR wire tendons with button heads and BBR strand tendons with wedges.

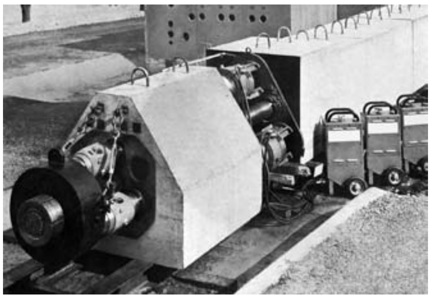
Full-scale installation and tendon replacement test with tendons consisting of strand and wire tendons.



This early BBR testing of tendons involved the construction of a special facility at the tendon assembly plant in Switzerland, in order that large tendons could be tested in conditions which simulated the environment of a reactor vessel.

Although in the sixties, at the beginning of this new application, some pressure vessels had been realised with tendons which are today considered quite small, the use of large capacity tendons soon became common practice. Since 1965, prestressing by post–tensioning has become a clearly established technique for pressure confinement in the nuclear power industry.

Today, the recognised adaptability and reliability of BBR prestressing systems for the post-tensioning of nuclear power plant pressure and containment vessels has made them some of the best known internationally.



TOP: Construction of bottom cap with buttresses for anchorages of the UK's Dungeness B pressure vessel.

BOTTOM: Testing of BBR anchor head. Stressing device consists of three 500 t jacks, hydraulic pumps and load cells.

Nuclear testing – with flying colours

The BBR VT CONA CMI system has passed all tests of high capacity tendons required by the Guidelines for European Technical Approval ETAG 013 with flying colours – and has even withstood more stringent voluntary testing commissioned by the dedicated BBR engineers.

From the very beginning, ever since the foundation of the BBR partnership in 1944, many hundreds of tests have been executed in different technical laboratories for the approval of various anchorage types in many countries. However, since 2002, BBR VT CONA CMI internal post-tensioning anchorage types have been developed and tested extensively in accordance with standards set by ETAG 013 – and have secured European Technical Approval (ETA). Static load, resistance to fatigue and load transfer tests were completed successfully according to these guidelines.

Although well in excess of the ETAG requirements, the team decided to go above eight million load cycles – already over four times more than required – in one additional voluntary test run. It was amazing that, even under these extremely hard conditions, the tendon endured this gruelling fatigue testing without any strands breaking.

In March 2007, the BBR team set a new world record with the successful certification testing of the high capacity BBR VT CONA CMI post-tensioning tendons with up to 61 seven-wire prestressing strands. Just a year later, this was topped by a further world record - the successful testing of the BBR VT CONA CMI with up to 73 strands – a PT tendon with an extraordinary breaking load of over 20,000,000 N! The tendon capacity is the highest possible which can be tested on European soil.

Inspection and improvement work

For the continuous safety of service of large tendons, accurate measurement of the stressing force and regular controls are of great importance. For many years now, BBR Network members have been carrying out lift-off tests and routine cable inspections and replacements.

Ringhals 2, Nuclear Power Plant, Sweden

Periodical surveillance procedures are as follows:

- Lift-off of the anchor head with the BBR automatic stressing device to determine the actual prestressing force – this is digitally recorded by an x-y-writer.
- The tendon is subsequently released and a single tensile element is extracted for corrosion examination and further testing in the technical laboratory.
- A new single tensile element is installed and the tendon is stressed again to its original prestressing force.

Utilising the latest technology for monitoring prestressing force, all types of BBR VT CONA CMI anchorages can be equipped with the BBR WIGAbloc compression force measuring system. It allows for long term tensile force measurements with digital control, memory and printing facilities.

In addition, the BBR Network has been assisting with the replacement of steam generators. This work requires a large hole to be cut in the one metre thick secondary containment wall. The BBR Network team removes both horizontal and vertical tendons before the cutting process – and destresses the wall on the opposite side to avoid unexpected forces developing in the wall – keeping it in balance – during the replacement work.

As well as preparing risk assessment and health & safety statements for each job, our staff have to undergo a three day training course which covers behaviour inside the special facility. They are carefully screened and personal radiation logs are maintained and provided by the owner.

Contemporary Nuclear Vessel Design

In nearly all projects, the basic structural design is a cylindrical vessel with flat end slabs or a convex dome. Practically all recent nuclear structures consist of two shells, the inner and the outer containment.

Today, post-tensioned nuclear structures have reached an outside diameter of 50 m and a height of 70 m of the inner shell with a capacity of 1,600 MW.

BBR PT TENDONS

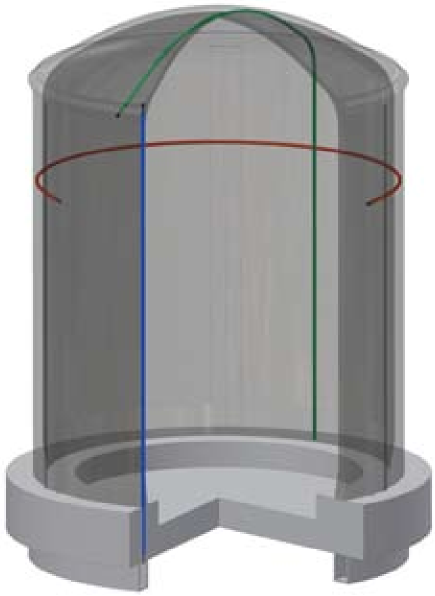
Three types of BBR post-tensioning tendons are typically used for the inner containment, as follows:

- **Vertical tendons for wall post-tensioning**
  The lower anchorage is situated in the roof of the tendon gallery and the higher anchorage is placed on the ring in the base level of the dome.
- **Horizontally looped tendons (hoop tendons)**
  These can accommodate a varying number of vertical buttresses (ribs) – for example, four buttresses with 180° tendon hoops or three buttresses with 240° tendon hoops. The tendons are anchored alternately in one of the vertical ribs and both anchorages are situated on opposite sides of the same rib. The current trend is to reduce the number of buttresses.
- **Horizontal end slab post-tensioning "cane shaped" tendons**
  These are placed in two right angled planes in the dome, which have a varying length. The lower anchorage is situated in the roof of the PT gallery and the upper anchorage is placed under the retaining ring of the dome.

BBR PROTECTION

During the entire lifetime of the pressure vessels, the greatest attention must be paid to the protection of the prestressing steel from corrosion. The BBR Network uses three different types of corrosion protection for nuclear tendons:

- **Cement grouted tendons**
  The cementitious grout surrounds the prestressing steel in an alkaline environment that inhibits corrosion. If there is a local fracture of a tendon, part of the prestressing force remains transmitted to the concrete due to the bond with the grout. However, grouted tendons cannot be visually inspected, mechanically tested or retensioned in the event of greater than expected loss of prestress.
- **Grease or wax grouted tendons**
  For these unbonded tendons, the prestressing force is transmitted to the concrete primarily at the location of the anchorages. Corrosion is prevented by grease, corrosion inhibiting compounds or wax. The tendons can be mechanically tested in-situ and the actual prestressing force can be monitored by lift-off tests or through permanently installed equipment. They can be retensioned and they can also be removed for visual inspection and eventually replaced.
- **Tendons protected with circulating dry air**
  For these unbonded tendons, the same properties and advantages apply as for the grease grouted tendons.



Bellefonte Nuclear Plant
Alabama, United States

#	Year	Name	Region	Capacity [MW]	Tonnage of Tendons [t]
65	1988	Bellefonte Nuclear Plant, Unit 1, Scottsboro, Alabama	Americas	1,256	1,724
64	1988	Bellefonte Nuclear Plant, Unit 2, Scottsboro, Alabama	Americas	1,256	1,724
63	1988	Braidwood Nuclear Power Station, Unit 2, Joliet, Illinois	Americas	1,067	1,452
62	1987	Byron Nuclear Power Station, Unit 2, Illinois	Americas	1,129	1,452
61	1987	Braidwood Nuclear Power Station, Unit 1, Joliet, Illinois	Americas	1,175	1,452
60	1987	Callaway County Nuclear Power Station, Unit 2, Fulton, Missouri	Americas	1,120	1,200
59	1987	Nine Mile Point 2 Sterling Power Project, Sterling, N.Y.	Americas	1,175	1,200
58	1986	Tsuruga Power Station, Unit 2, Fukui Prefecture	Asia	1,115	1,500
57	1985	THTR Kernkraftwerk, Uentrop-Schmehausen	Europe	296	1,570
56	1985	Forsmark Power Plant, Unit 3, Östhammar	Europe	1,050	1,020
55	1985	Dungeness B-2 Nuclear Power Station, Kent	Europe	600	2,043
54	1985	Byron Nuclear Power Station, Unit 1, Illinois	Americas	1,129	1,452
53	1985	Wolf Creek Power Station, Unit 1, Burlington, Kansas	Americas	1,150	1,200
52	1985	Tyron Nuclear Power Station, Unit 1, Durand, Wisconsin	Americas	1,100	1,200
51	1984	Lemoniz Power Plant, Unit 1, near Bilbao	Europe	930	913
50	1984	Lemoniz Power Plant, Unit 2, near Bilbao	Europe	930	913
49	1984	Midland Nuclear Power Station, Unit 1, Michigan	Americas	750	780
48	1984	Midland Nuclear Power Station, Unit 2, Michigan	Americas	750	780
47	1984	La Salle County Nuclear Power Station, Unit 2, Illinois	Americas	1,078	363
46	1984	Callaway County Nuclear Power Station, Unit 1, Fulton, Missouri	Americas	1,120	1,200
45	1983	Embalse Nuclear Reactor, Rio Tercero, Cordoba	Americas	600	760
44	1983	Dungeness B-1 Nuclear Power Station, Kent	Europe	450	2,043
43	1982	Centrale Nucléaire Gentilly 2, Québec	Americas	645	750
42	1982	Lepreau Nuclear Generating Station, Point Lepreau	Americas	635	800
41	1982	Wolsong Nuclear Reactor, Unit 1, near Pusan	Asia	629	800
40	1982	Ringhals Power Plant, Unit 4, Vaerobacka	Europe	915	900
39	1982	Virgil C. Summer Nucl. Station, Unit 1, Fairfeld County, S.Carolina	Americas	900	1,044
38	1982	La Salle County Nuclear Power Station, Unit 1, Illinois	Americas	1,078	363
37	1981	Cernavoda Power Station, near Fetesti	Europe	600	750
36	1981	Joseph M. Farley Nuclear Plant, No. 2, Houston County, Alabama	Americas	814	800

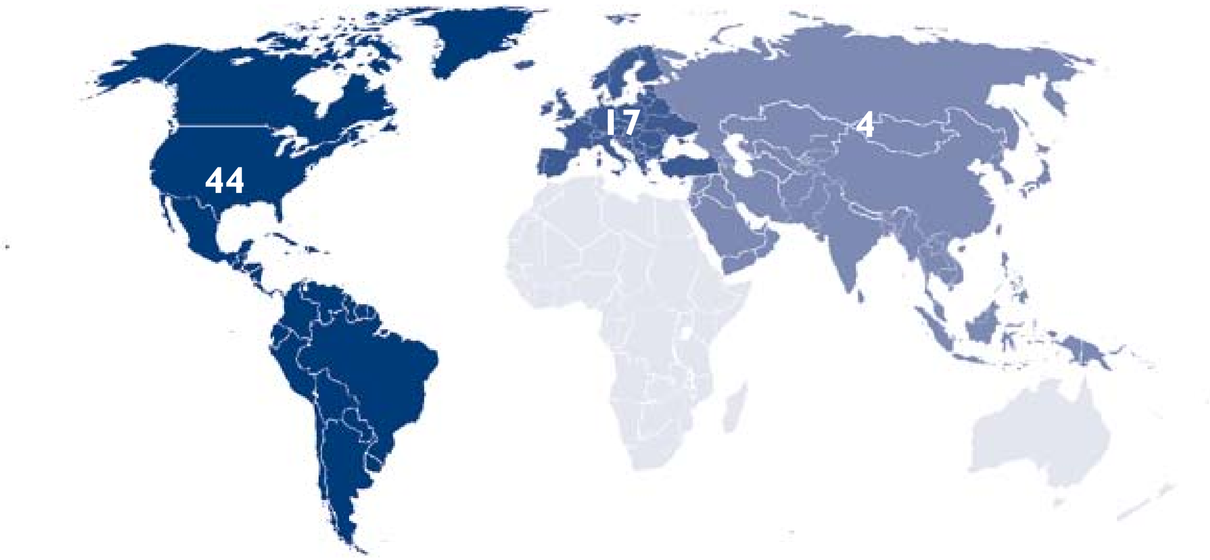
#	Year	Name	Region	Capacity [MW]	Tonnage of Tendons [t]
35	1980	Olkiluoto Power Plant, Unit 2, near Pori, Björneborg	Europe	710	510
34	1980	Genkai Power Station, Unit 4, Saga Prefecture	Asia	1,180	1,471
33	1980	Ringhals Power Plant, Unit 3, Vaerobacka	Europe	915	900
32	1980	Wm. H. Zimmer Nuclear Power Station 1, Moscow, Ohio, Clermont C.	Americas	840	277
31	1979	Gentilly Nuclear Power Station, Québec	Americas	250	526
30	1978	Russelville Nuclear Power Station, Unit 2, Arkansas	Americas	930	1,113
29	1977	Crystal River Nuclear Power Station, Florida	Americas	821	1,302
28	1977	Joseph M. Farley Nuclear Plant, No. 1, Houston County, Alabama	Americas	804	800
27	1976	Fort St. Vrain Power Station, Platteville, Colorado	Americas	330	454
26	1976	Calvert Cliffs Nuclear Power Station, Unit 2, Lusby, Maryland	Americas	825	900
25	1975	Genkai Power Station, Unit 3, Saga Prefecture	Asia	1,180	1,483
24	1975	Calvert Cliffs Nuclear Power Station, Unit 1, Lusby, Maryland	Americas	825	900
23	1975	Millstone Nuclear Power Station, New London, Connecticut	Americas	860	928
22	1975	Trojan Nuclear Plant, Portland, Oregon	Americas	1,080	1,021
21	1974	Oskarshamn Power Plant, Unit 2, Figeholm	Europe	595	605
20	1974	Ringhals Power Plant, Unit 1, Vaerobacka	Europe	750	350
19	1974	Ringhals Power Plant, Unit 2, Vaerobacka	Europe	800	900
18	1974	O'Conee Nuclear Power Station, Unit 3, Clemson, South Carolina	Americas	860	1,009
17	1974	Three Mile Island Power Plant, Pennsylvania	Americas	776	1,447
16	1974	Russelville Nuclear Power Station, Unit 1, Arkansas	Americas	846	1,113
15	1973	O'Conee Nuclear Power Station, Unit 1, Clemson, South Carolina	Americas	860	1,008
14	1973	O'Conee Nuclear Power Station, Unit 2, Clemson, South Carolina	Americas	860	1,008
13	1973	Turkey Point Nuclear Power Station, Unit 4, Biscayne Bay, Florida	Americas	666	813
12	1973	Fort Calhoun Station, Unit 1, Nebraska	Americas	438	908
11	1973	Zion Nuclear Power Station, Unit 1, Illinois	Americas	1,040	817
10	1973	Zion Nuclear Power Station, Unit 2, Illinois	Americas	1,040	817
9	1972	Centrale Nucléaire Bugey I, Bugey	Europe	540	4,313
8	1972	Point Beach Nuclear Power Plant, Unit 2, Two Rivers, Wisconsin	Americas	495	727
7	1972	Turkey Point Nuclear Power Station, Unit 3, Biscayne Bay, Florida	Americas	666	812
6	1971	Oskarshamn Power Plant, Unit 1, Figeholm	Europe	440	600

#	Year	Name	Region	Capacity [MW]	Tonnage of Tendons [t]
5	1971	Beznau Nuclear Power Station, Unit 2, near Brugg	Europe	350	250
4	1971	Palisades Nuclear Power Plant, South Haven, Michigan	Americas	635	872
3	1970	Point Beach Nuclear Power Plant, Unit 1, Two Rivers, Wisconsin	Americas	485	726
2	1969	Beznau Nuclear Power Station, Unit 1, near Brugg	Europe	350	250
1	1969	Robert Emmet Ginna Power Plant, Brookwood, New York	Americas	470	145

Total	52,954	66,223
Maximum	1,256	4,313
Average	815	1,019

Number of projects per region

Total	Americas	Europe	Asia
65	44	17	4



Projects in the following countries

Argentina, Canada, Finland, France, Germany, Japan, Korea, Romania, Spain, Sweden, Switzerland, United Kingdom, United States

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 six decades of experience have resulted in BBR technology being applied to 65 nuclear installations and, in the process, we have continued to refine and enhance our range.

Technology does not however develop by itself - all 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.

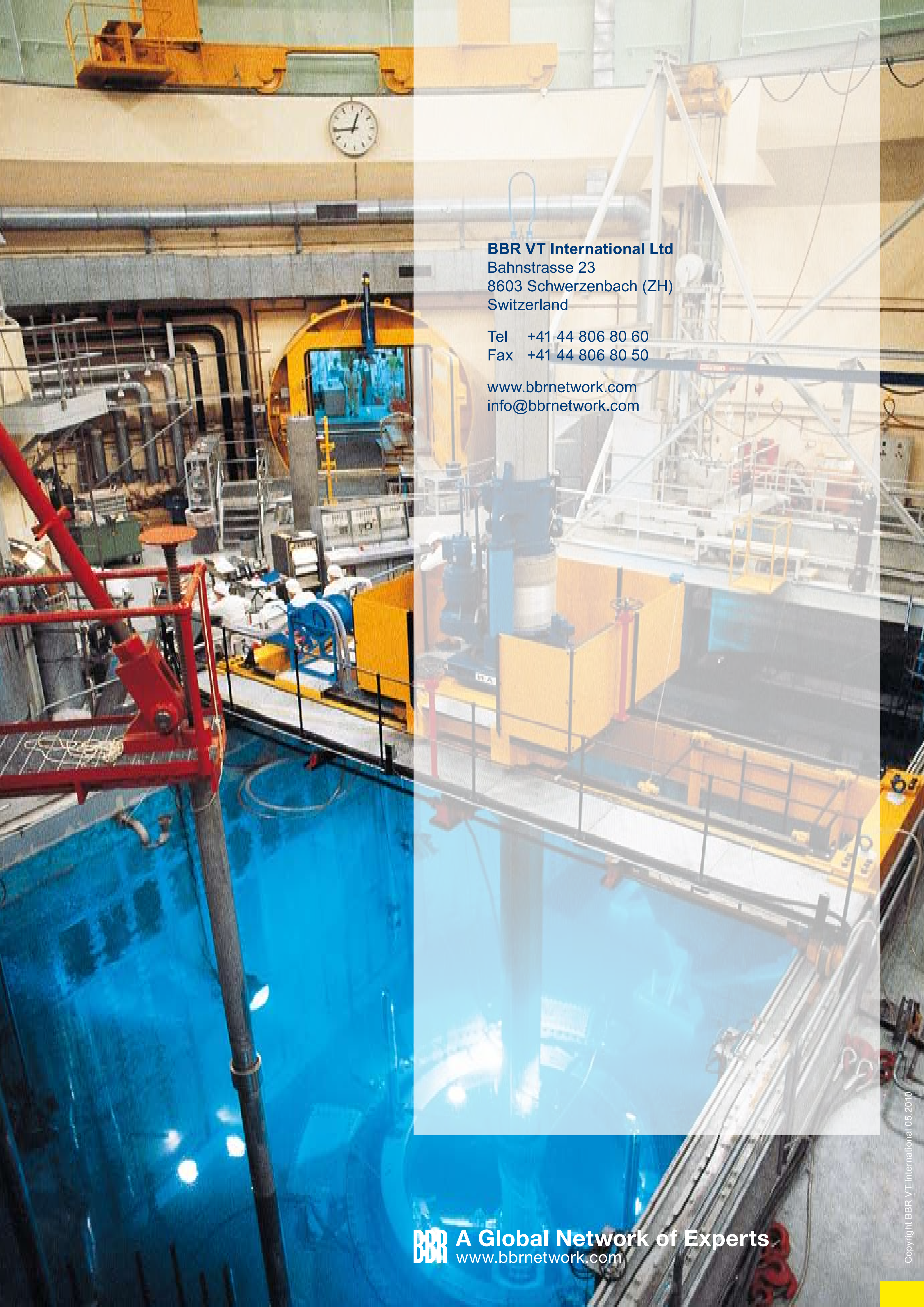
Our well-established worldwide network is supported in the development of nuclear power structures by our Special Projects Team who will help to specify and procure the systems required. So, local knowledge synchronises with international know-how to realise projects – some large, some smaller, but always technically excellent and fit for purpose!

A Global Network of Experts - Since 1944 -

Beznau Nuclear Power Station
near Brugg, Switzerland

"By far the best proof is experience."

Sir Francis Bacon
English author, courtier & philosopher
1561 – 1626



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