One of the most unique and sophisticated pressure sensors is the fused quartz bourdon tube or capsule. The fused quartz bourdon tube should not be confused with the quartz resonator pressure sensors, which use quartz crystal and are currently designed and marketed by companies such as Paroscientific and Quartzdyne. Fused quartz tubing is manufactured by melting naturally occurring high purity quartz crystals at approximately 2000°C and then extruding the melted quartz into various diameters and wall thicknesses. This type of tubing is transparent and looks almost like glass.

Some of the early development of the quartz bourdon can be traced back to Sam Worden, who was most noted for his pioneering work in gravimeters. The Worden Gravity Meter has the capability of measuring relative gravity to 1 part in 100,000,000 or a difference in elevation of only 1 inch. Before Sam Worden started fabricating quartz bourdon tubes for Worden for Ruska Instruments (early 1960's), he built some low resolutions models for use in scientific labs. Walter Ruska, the founder of Ruska Instruments, left Ruska before any developmental or engineering efforts were started at Ruska on quartz measuring instruments.

Why fused quartz? Many would ask why fused quartz was chosen to be a pressure sensing element. Dating back to the use of fused quartz in gravimeters, it was well known that it made an almost perfect spring material. Since fused quartz had a very low coefficient of thermal expansion, low thermoelastic modulus and low internal viscosity the “stage was set” to use fused quartz as the break through bourdon material.

In 1962 Willard E. Buck received a patent for a precision barometer that used a quartz bourdon as the pressure sensing element. The key design objectives were higher resolution and improved portability. The fate of this particular patent and design relative to commercialization is unknown.

At the base of the quartz bourdon tube was a mirror that was used to detect the position or deflection of the bourdon tube when pressure was applied. A light source aimed at the mirror reflected back on to a pair of photocells that indicated the amount of angular deflection of the bourdon tube. A mechanical digital counter would indicate the amount of offset from null. The counter reading multiplied by a scale factor provided a number that was proportional to the pressure applied to the bourdon tube. The TI 140 Series quickly found applications in avionics, calibration laboratories, and other applications that required a high level of accuracy and performance. The early TI bourdon capsules were capable of measuring pressures up to 500 psi and could be used to measure gauge, absolute or differential pressure. The reference side (or area surrounding the bourdon)
Lloyd Linton (Chief Engineer) teamed up with Ray Worden to design the quartz bourdon tube for this next generation Ruska product - the XR-38 – which was introduced by Ruska to the precision pressure market in 1968.

Ruska XR-38 Sensor

In the late 1960’s Texas Instruments introduced its second generation of quartz bourdon instruments, which was the TI-145 (gauge) and TI-156 (controller). With TI's focus on hand-held calculators, integrated circuits and other fast developing markets, it was difficult to obtain funding for the pressure instruments division. So Jerry Fruit made the decision to leave TI and start a new company dedicated solely to precision pressure instruments. This new company would be named Mensor. Most of the Mensor founders worked at TI in the pressure instruments group including the engineering, production and sales departments.

Mensor Corporation was founded in 1969 to take the fused quartz sensing technology to the next level of performance. The Mensor “sensor” was similar to the design of the TI capsule in that it also used optical sensing in order to eliminate any friction or thermal effects being applied directly to the quartz bourdon. A small circular mirror, attached to the quartz bourdon, reflected a light back on to photocells. When pressure was applied to the quartz bourdon, the mirror would rotate relative to the magnitude of the pressure applied and produce an offset voltage or error signal from the photocells.

Mensor Quartz Sensor

The Mensor fabrication process started with high purity quartz tubing (for example, 8 mm OD by 6.5 mm ID). A custom lathe and a set of torches were used to wind a hollow quartz spring or bourdon on a carbon mandrel. The torches were used to soften the quartz tubing such that it could be wound or formed into a helix which would eventually be about 28 to 30 coils on the final assembly. The exact pressure range was determined by the size of the tubing, the speed of the lathe, the feed of the lathe and the amount of back pressure applied to the inside of the tubing. Different pressure ranges had different cross sectional areas and different wall thicknesses. Adjustments to the exact pressure range could be accomplished by etching the quartz spring with hydrofluoric acid. The helical quartz bourdon would then become an integral part of a complete bourdon assembly that included; (a) quartz mirror, (b) quartz tension spring, (c) mounting block, (d) housing, (e) pneumatic fittings and (f) glass sleeve. All of the quartz components were fused together into a single quartz assembly. It is easy to see when one looked at the intricate quartz bourdon assembly why it is considered to be the work of a craftsman and almost a work of art.
The first product introduced by Mensor was the Quartz Manometer (QM) in 1970, followed by the Quartz Manometer/Controller (QM/C) in 1971. In the early 1970’s the QM was used for metrology applications primarily in calibration labs, avionics and research. The QM as first introduced was not a direct reading instrument. Special interpolation charts were used to determine the exact pressure reading. Development work began early in the 1970’s to produce a Mensor direct reading instrument. In 1972 Mensor introduced the first quartz bourdon pressure measurement instrument that had the ability to provide direct pressure readings in pressure units (i.e., in.Hg, mbar, kPa, etc.). The direct reading design developed at Mensor was patented and made the fused quartz bourdon instruments even easier and faster to use. In 1976 Mensor introduced a digital pressure gauge (Model 11600), which used a fused quartz bourdon in a force-balanced configuration. Whereas the Mensor QM and QM/C had removable capsules, the Model 11600 had a dedicated sensor that was not removable. Mensor also used the fused quartz bourdon in its second generation pressure controller (Model PCS200) in 1983.

In the early-1970’s Ruska decided to develop their third generation pressure instrument employing a quartz bourdon tube in also in force balanced design. This instrument known as the DDR-6000 was also direct reading and was designed for precision pressure measuring and controlling applications. The DDR-6000 quartz assembly was reminiscent of the Worden Gravity Meter quartz assembly in terms of complexity and physical appearance.

At the beginning of the 1990’s Mensor saw potential opportunities and advantages with silicon piezoresistive sensors and began development of a new line of pressure instruments. During the early 1990’s Mensor continued to sell and service quartz bourdon products, including the TI products. By the mid-1990’s Mensor had stopped all production of quartz bourdon instruments.

After a 50 year history of quartz bourdon pressure instruments, Ruska is now the only company that is still manufacturing and selling quartz bourdon tubes. In 1993 Druck acquired Ruska and three years later GE acquired Druck. While Druck continued to use the Ruska trade name, it appears that the both the Druck and Ruska products and models will eventually become GE labeled. The Ruska 7250 is now showing the GE PACE 7000 brand.

It is interesting to note that the three companies that capitalized on the fused quartz bourdon as a precision pressure sensing element were all located in Houston, Texas. The contributions of great minds like J.B. Damrel Jr. and Jerry Fruit at Texas Instruments, Ray Worden, Kurt Solis and Lloyd Linton at Ruska and then Jerry Fruit at Mensor drove the development, design and commercialization of a technology that has spanned a period of 50 years and is still in use by Ruska today. This article is dedicated to these pioneers that forged the “technology trail” for the fused quartz bourdon tube in precision pressure instruments.
1964 Ruska acquires Worden Labs
1966 Patent issued to Pete Damrel & Jerry Fruit at Texas Instruments
1968 Ruska introduces Quartz Pressure Gauge (Model XR38) and the Model 3820 Pressure Test Set
1969 Mensor founded in Houston, Texas
1969 Mensor introduces Quartz Manometer (Model 10100)
1970 Mensor introduces Quartz Manometer/Controller (Model 10205)
1972 Ruska introduces Quartz Pressure Gauge/Controller (Model DDR6000/6010)
1973 Patent issued to Jerry Fruit at Mensor
1975 Patent issued to Ray Worden, Kurt Solis & Lloyd Linton at Ruska for DDR6000
1976 Mensor introduces Quartz Digital Pressure Gauge (Model 11600)
1976 Mensor introduces Quartz Digital Pressure Transducer (Model 11603)
1983 Mensor introduces Quartz Pressure Controller (Model PCS200)
1980’s Texas Instruments sells Quartz Product Line to Halliburton
1980’s Ruska introduces Model 7000/7010’s.
1987 Mensor introduces Quartz Pressure Gauge (Model PCS100)
1990 Mensor acquires Quartz Product Line from Halliburton/HGS
1990 Halliburton sells Worden Gravity Meter Co. to Bob Neese
1992 Mensor discontinues manufacture of all quartz sensors products
1993 Druck acquires Ruska
1996 GE acquires Druck
2006 WIKA acquires Mensor