



From stargazing to drinks dispense

Infrared thermometers in compressed gases

Dr. Peter Watters explains several case studies in monitoring gas cylinder temperatures with infrared thermometers and looks at potential future applications.

About 12 years ago I stumbled into a public lecture by an innovative Belfast manufacturing company called Andor, who had developed very clever (and expensive) infrared cameras, primarily for looking at stars. As part of the presentation touched on hydrogen fusion and the dire consequences of running out of hydrogen, and as an industrial engineer I suppose I remembered it.

A couple of years later we had a problem with filling drinks dispense CO₂-nitrogen mixture cylinders at low temperatures. I stumbled upon a Calrex Electronics infrared thermometer and this short article relays here what happened next.

Gas cylinder temperature
We have now been using Calrex

Electronics infrared sensors on drink dispense cylinders for over 10 years. We had a problem related to the low temperature of seamless steel cylinders at the start of filling. If the base was < 5°C we had a problem, >= 5°C we did not.

The unique selling point (USP) of the Calrex in 2004 was being scalable, from -20°C to +100°C. We were able to determine the cylinder base temperature through the ice built up in liquid CO₂ filling. The top of these seamless steel alloy cylinders was found to be over 40°C with some mixtures. As we moved the focus of the infrared sensor up and down, we could see the different temperatures on the cylinder wall and were impressed by the speed of response of the sensor. (250m/Sec, 95% range)

In 2006 we started to look at using infrared thermometers to look at the wall

temperature of small medical cylinders, including steel and aluminium alloys and composite wrapping. Our conventional sensors could not stick to the composite, and it acted as insulator. We found that the sensors worked very well and this article reflects some lessons learned.

Those Calrex sensors were stainless steel cylinders, approximately 18mm in diameter and 84mm long, with a lens at one end and a 4-20mA 24 V DC lead at the other. We used an infrared thermometer with a range of -20/+100°C – **Figure 1** shows the lens approximately 150mm from a small medical cylinder.

Infrared thermometers
A cylinder radiates heat as it is filled, and we have measured temperatures in Ireland from -30°C to +55°C. The cylinders emit infrared radiation of a

frequency directly linked to the surface temperature. Each different metal surface has different emissivity of infrared radiation, but the frequency is always related to the temperature.

We looked at different cylinder alloy/wrapping combinations and these materials emitted infrared of different strength. Aluminium was not the ideal material as emissivity was lower than steel and polymer cylinder coatings could also absorb infrared radiation.

Over the space of six months we established that if we placed our infrared sensors approximately 100mm away from the cylinder aluminium alloy, seamless steel and composites all worked. The system was then developed with multiple infrared thermometers to look at all the cylinders filled.

Where do you measure temperature?
The next question was, where to look at the cylinder to get the best results for temperature measurement? Our observations had shown aluminium alloy composites, warmed up from the base, and the neck area was cooled by gas flow. The composite wrapping acted as an insulator.

We noted that the cylinder would develop a uniform temperature near to maximum pressure, and the exact point of the maximum would vary with filling speed.

Figure 2 shows the increase in temperature during a fill with the sensor looking at the cylinder base or wall. After a stakeholder meeting we chose the position 150mm below the cylinder valve, see **Figure 1**. Here, the sensor was always looking at a section of parallel cylinder wall for all the designs.

Infrared thermometer performance
Up until this point our work had found that the infrared sensor was much simpler for use with varying cylinder designs and sizes, without having to make contact with the cylinder. They were, thus, an acceptable alternative to the PT100 Thermocouples that had been used before.

The big advantage then came from being able to see the same point on all of the cylinders in a batch (initially 10). Infrared



Figure 1 – Infrared sensor 100mm from two cylinders

thermometers are calibrated against a black body source that emits infrared radiation at a fixed temperature (60°C for gas cylinders). As a routine human check, I used to pass my morning coffee past each one to see the temperature response.

Purge gas – Closed valves
One medical oxygen system was designed to fill medical oxygen cylinders, and **Figure 3** (page 54) shows the pressure increase in green as the initial 40 Bar purge enters the cylinders. The gas is then released and the red and blue lines go up and down.

If all the infrared sensors did not see this response, the filling process stopped,

as either the infrared sensor was obscured or the cylinder valve was closed.

Observations of the cylinders on the filling machine before filling started showed the large variation in temperature caused by blowing-down the returned gas within the cylinder. In tests we were able to see a 20°C drop in cylinder temperature after blow-down.

The filling control system was set up to see the warmest (red trace on **Figure 3**) and coldest (blue trace on **Figure 3**) cylinder in the batch, and only allow filling when the difference was small enough to ensure that all the cylinders would be within specification on pressure with a 99.7% confidence. ▶

Figure 2 – Two Temperature Sensor Locations (final fill temp uniform at 38°C)

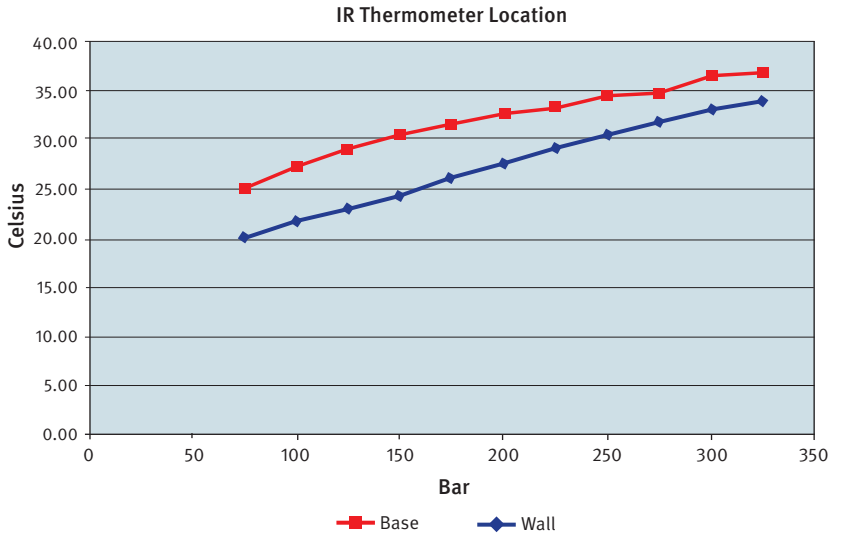
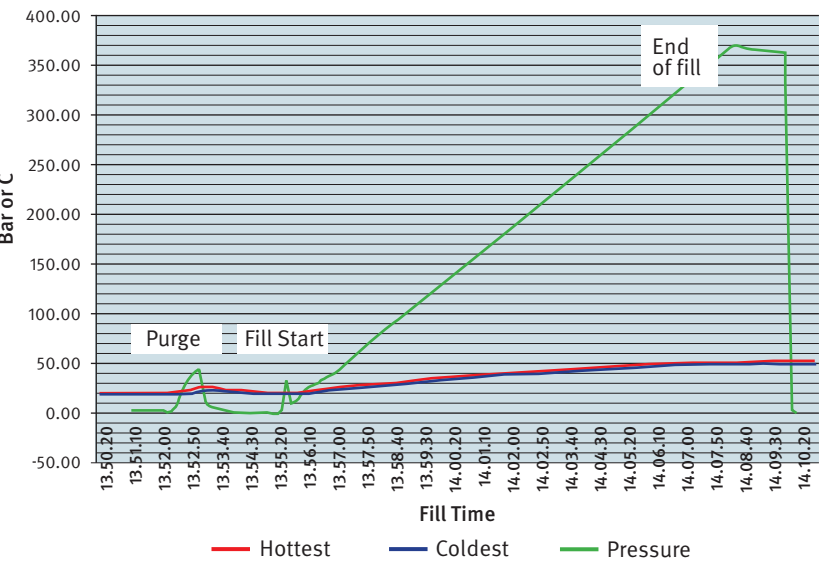


Figure 3 – Filling Run for 10 x 10 litre 300 Bar Cylinders Filled



► Filling rate and 99.7% conformity

As we looked at the data from the filling we noted a maximum temperature on small composite cylinders of 50-55°C. This broadly agreed with data from the cylinder manufacturer. They recommended a slower fill rate of 30 Bar increase/minute, with fast filling air to 300 Bar achieving 50°C in 30-60 seconds filling.

"...we have moved on to look at other applications for infrared thermometers in gas cylinder filling"

In the end we set the system up on a 600-second fill, with a linear pressure rise (Figure 2). The temperature continued to rise for approximately 90 seconds after the end of the fill. We found that the filling process became reproducible, with the only significant change being the initial start temperature of the cylinder. This was variable with the seasons and could be controlled by holding cylinders near to the filling room before filling.

This filling system, with the changes linked to the infrared thermometers, meant that we achieved 100% pressure conformity in the first year after commissioning.

Future applications

Since 2008 we have moved on to look at other applications for infrared thermometers in gas cylinder filling.

One application of infrared thermometer could be to monitor methane (CNG) filling, as it is the permanent gas with the largest pressure temperature compensation curve.

Unfortunately, this would mean the infrared thermometers could only work with large goods vehicles and buses, where the sensor on the filling head could see the cylinder during the fill. Here, the fill control system could be optimised to get a uniform cylinder temperature and minimise the temperature rise in filling. An alternative solution is to build an infrared thermometer into the pressure monitor on all CNG vehicle tanks.

Hydrogen cylinders don't warm up as much as methane, but the higher fill pressures of 350-700 Bar push cylinder temperatures up to over 85°C, as William Liss of the Gas Technology Institute showed, in 2002*.

Since 2008 sensor manufacturer Calex has been able to extend its sensors to a -40°C/+2450°C range and the -40/+100°C range would be ideal for cylinder filling most gases.

The original 60°C Black Body source can now be supplied with other fixed temperatures.

The Sensors can be supplied with RS 485 communications and controls to reduce the modifications required by PLC controls by generating digital outputs.

Conclusion

We hope that this article offers some ideas about how Infrared thermometry can be used to:

- Monitor cylinder filling temperatures through ice and composite materials, across the complete length of the shell
- Minimise the developed filling pressure
- Ensure that the fill valve is open in batch filling
- Help control batch filling, to improve the quality of product delivered.

Further still, we hope that this case study on the application of existing equipment to a new application is a good example of open innovation between an operating unit of a major gas company, a local control company, a small UK manufacturer, and a small R&D consultancy. 

ABOUT THE AUTHOR

Dr. Peter Watters, CEng FIMechE FIEI, is a Mechanical Engineer, who spent 10 years in BOC Gases and 20 as a consultant. His PhD studied the Movement of the Human Patella, and his subsequent career has involved a number of new applications of technology to solve problems not originally considered.

REFERENCES

Andor Technology, Ltd, formerly of Queens University, Belfast, became an Oxford Instruments company in January 2014 to spearhead strategic expansion into the Nano-Bio arena.

*Proceedings of the US DOE Hydrogen programme review NREL/CP-610-32405. Development of a natural gas to hydrogen fuel station, WE Liss, M Richards, Gas Technology Institute, US.