ABB MEASUREMENT & ANALYTICS | APPLICATION NOTE

Carbon Capture
Utilization and Storage

Energy storage system

Introduction

Given the status of the ongoing initiatives to fight climate change, and the insufficient progress made so far in the decarbonisation challenge, there is a growing need for carbon capture, utilization and storage (CCUS) to help with the energy transition and decarbonization of industrial processes, also considering the growing urgency to address climate change felt by the general public, as well as by policy makers and investors. All these factors are accelerating the deployment of CCUS solutions in many regions of the world, covering many industrial sectors.

Analysts and no-profit organizations involved in climate and energy, like the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC), are indicating CCUS as a key pillar in the overall effort to reach the Paris Agreement's (COP21) target of limiting the global temperature rise to 1.5 °C.

As of March 2024, the CCUS project pipeline is rapidly scaling up, with an average increase of 60% on a yearly basis over the last four years, while IEA predicts that by 2050 up to 56% of primary chemicals production will be CCUS-equipped.

The chemicals sector plays an important role in this scenario, since the chemical industry is both a producer and a potential consumer of CO2, as many products and processes associated with organic chemistry require carbon as an essential element to form complex chemicals compounds, thus captured CO2 has high potential for replacing fossil fuels as carbon feedstock. At the end of 2023, the ethanol industry had the second largest number of CCUS facilities worldwide, while hydrogen, ammonia and fertilisers combined represent the fourth largest. As indicated by many, CCUS represents a key decarbonisation technology for the chemical industry, especially for the chemicals causing the largest share of carbon emissions: ammonia, methanol, urea, ethylene, propylene, xylenes, benzene, together with an improvement of process efficiency, the recycling of chemicals towards a circular economy, and the use of hydrogen and biomass as feedstocks. Replacing fossil feedstocks with renewable alternatives is another key pillar of the energy transition and decarbonization challenge of the chemical sector where, in addition to green hydrogen (hydrogen obtained via water electrolysis using renewable energy) and biomass, captured CO2 is considered a promising feedstock to replace fossil imports in organic chemistry, especially when combined with green hydrogen.

Currently the most mature and better-known technology for CO2 capture involves an amine-based chemical absorption process, usually using monoethanolamine (MEA), for post-combustion CO2-rich flue gases. In recent years there have been already several successful applications of post-combustion carbon capture to the chemical sector, for example in ammonia and methanol production processes, and an increasing number of CO2 utilization projects, where CO2 captured from various production sites is used as chemical feedstock to produce ethylene, propylene, methanol, ethanol, urea, olefins and BTX aromatics. The process of capturing, transporting, using or storing CO2 has complex requirements, combining the needs of process control and optimization, with those of custody transfer and reporting, requiring a portfolio of instruments to ensure optimal performance, trustworthiness and compliance with regulations.

Application
The CCUS process chain comprises the steps of separating and capturing the CO2, compressing it for transport, temporary storage and, finally, underground storage or utilization of the captured CO2 as feedstock to produce high-value products, like carbon-containing chemicals. The most common strategy for capturing CO2 is the so-called post-combustion carbon capture, where the CO2 is separated from a CO2-rich flue gas originating from the combustion of fossil fuels.

Different processes are available to separate CO2 from flue gas stream, including chemical and physical absorption, adsorption techniques, cryogenics methods, membrane separation techniques, methods based on gas-solid reactions and natural integration processes.

Chemical absorption represents today the most used carbon capture approach, where a lean chemical solvent strips the CO2 from a CO2-rich flue gas stream, with amine-based scrubbing being the dominant technology. The chemical absorption process includes an absorber, where the flue gas runs upwards through a solution containing the lean solvent, allowing the CO2 to bind with the solvent.

The CO2-rich solvent is then sent to the regenerator, where high temperatures are used to “strip” the solvent, separating the CO2 from it, thus creating a very pure CO2 stream, ready for transportation or direct use. The regenerated solvent is then sent back to the absorber, to repeat the cycle.

In such processes it is of great importance to ensure the safe and efficient operations of the plant, considering its significant energy requirements, and to monitor the remaining CO2 content of the flue gas, and the purity and composition of the CO2 stream leaving the capture site.

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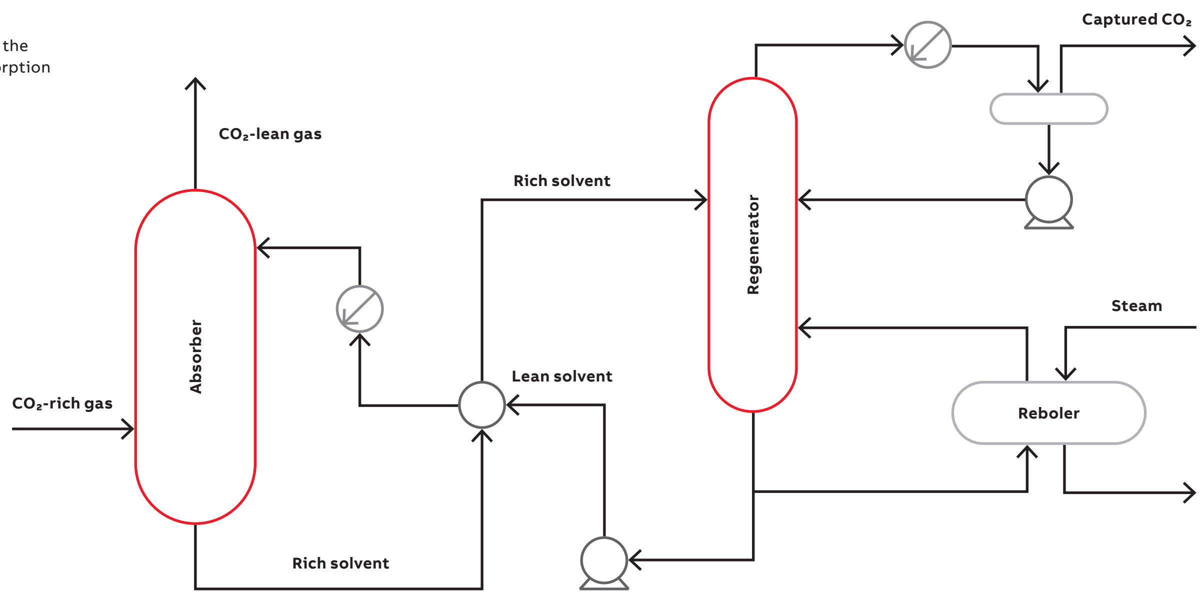
01 Example of the chemical absorption process



The challenge
There are many challenges in establishing safe, efficient and practical operation of CCUS processes, and measurement and analytics solutions play an important role both in control, monitoring and optimization of capture processes and transport systems, and in metering CO2 for custody transfer and regulatory purposes.

It is important that the captured CO2 is measured and monitored across all stages of the CCUS value chain to ensure trust in all transactions regarding CO2 capture, transportation and use, and to comply with regulations, like the EU ETS. Measurements are also crucial for ensuring that the capture and transport processes are operating in a safe and efficient manner.

Measurement solutions for CCUS should include measurements of:

- Flowrate and CO_2 content of the flue gas entering the absorber (to validate CO_2 capture rate and for compliance with subsidy agreements).
- Content of SO_2, NO_x in the flue gas entering the absorber, to prevent solvent ageing.
- Temperatures and pressures in the absorber and regenerator columns.
- Flowrate of solvent to and from the absorber.
- Solvent analysis with FTIR to measure solvent strength (CO_2 loading) and presence of contaminants and degradation products.
- Flowrate of steam and temperature in the regenerator boiler.
- Flowrate of captured CO_2 and purity of the CO_2 stream (for custody transfer and compliance).
- Physical properties (dewpoint) of the mixture composing the captured CO_2-rich stream.
- Analysis of H_2O, H_2S and O_2 in the CO_2 stream to prevent corrosion of assets.
- Emission monitoring on top of the absorber, related to usual (NO_x, SO_2, CO, CO_2 etc.) and solvent related emissions (emissions of Amines and carcinogenic Nitrosamines etc.).

One of the main challenges for measurement system is that the CO_2 could be a gas, a liquid, or a supercritical fluid at various stages of the CCUS value chain, and that the CO_2 critical point and the boundary between these phases lie within the range of normal operating conditions of carbon capture and transportation systems. Moreover, the presence of contaminants in the CO_2 stream adds another layer of complexity to the measurement challenges and the wetted material selection of these devices.

The solution

Continuous measurement of temperatures and pressures across the various stages of the carbon capture process, together with the flowrate of the solvent, provides the basis for real-time approaches to monitor, control and optimize the operation of the capture plant, allowing safe operation and efficient use of energy. The use of accurate flowmeters, flow computer and gas analysers would be the key solution for monitoring the performance of carbon capture and transportation systems, and for all requirements regarding custody transfer, reporting and compliance to regulations.

ABB's solution

What does ABB offer?

CoriolisMaster mass flowmeter

Directly measuring mass flow without the need for density-based corrections is ideal to achieve high accuracy while measuring CO_2-rich streams in challenging conditions.

As such, Coriolis flowmeters are the ideal candidate for CO_2 flow measurement for monitoring, reporting, and to ensure compliance with regulatory requirements. CoriolisMaster can measure CO_2 in its liquids, gaseous or superctrical state offering a wide flexibility and covering all phases of the carbon capture, transportation and use value chain.

CoriolisMaster is also able to provide precise measurement of mass and volume flow, density, temperature, and concentration, reducing overall costs and maintenance requirements, and it could also be used to measure lean and rich amine flows. Coriolis flow meter is inherently flexible in being able to measure the flow of gases or liquids and provide customers with large turn-down capabilities. Its built-in ABB Ability verification solution "VeriMass" allows for continuous and remote verification of the status of the meter as well as its accuracy and repeatability.

SwirlMaster and VortexMaster vortex flowmeter

The post-combustion carbon capture process requires flow measurements for different working fluids in different parts of the process, for example for pipelines transporting CO_2, lean and rich amine, steam, etc. VortexMaster vortex flowmeter, and SwirlMaster swirl flowmeter offer accurate measurement of the operating volume flow for gas and liquid mediums, and the integrated flow computer allows the direct conversion to standard volume or mass flow if provided with the necessary pressure and temperature measured variables, thus compensating their effects.

SwirlMaster is the ideal device for demanding installation places, where almost no other measuring device with similar performance can be installed due to their straight piping requirements, for example where the installation space is narrow. SwirlMaster's flexibility in installation, due to low required inlet and outlet sections, can save up to 75% straight pipe run and enables installations in almost impossible situations.

ProcessMaster electromagnetic flowmeter

Proven to be tough, reliable and incredibly easy to work with, ProcessMaster FEP610 and FEP630 series deliver the power to solve the most demanding process applications with conductive liquids.

This innovative, next generation electromagnetic flowmeter range provides a modular transmitter design combined with SmartSensor technology and built-in verification, technical advances that deliver a clear business and performance benefit. They are well suited for flow measurements of chemical solvents and corrosive liquids, making them a good fit for CO2 capture applications, including flow measurements of CO2-lean and CO2-rich amine lines, and cooling system lines.

SensyMaster thermal mass flowmeter
The SensyMaster FMT400 series offers a high quality and cost-effective solution for precise and dynamic direct mass flow measurements of gases in low and medium pressure conditions to meet the needs of all industrial applications with high accuracy and extended functionality for advanced industrial applications. Within CCUS processes thermal mass flow meters are used to measure with high accuracy and repeatability the flow of the plant gas circulation and recycling. Especially in low pressure applications where most other principles fail, SensyMaster shows its strengths and shows unrivalled accuracy and turn-down ratios.

OriMaster compact orifice flowmeter
Devices based on orifice plates remain one of the bestselling flow metering technologies. As well as measuring flow, they are used to restrict the flowrate to a certain value or to reduce the pressure at a certain flowrate. The technology is well-known and thoroughly proven and is available from ABB in a wide range of designs to suit most applications. Orifice plate flowmeters, based on the use of high accuracy ABB differential pressure sensors, are applicable for a wide range of temperature and process conditions, with the lowest capital cost. They are well suited for applications where density changes within the process temperature range are well known, such as measuring the steam and the coolant flowrate in the carbon capture process.

NINVA non-invasive temperature transmitter
ABB innovative NINVA non-invasive temperature sensor allows to measure process temperature while eliminating the need for a thermowell, thus avoiding process intrusion and all problems related to corrosion and erosion, enhancing safety and reducing installation costs. NINVA has the same accuracy, repeatability and response time of traditional temperature transmitters based on a thermowell, with reduced risks and better CAPEX and OPEX cost efficiency.

Temperature transmitters
SensyTemp TSP100 and TSP300 series of temperature sensors are suitable for several measurement applications around the carbon capture process, including the absorber and regenerator units of CO2 amine-based capture plants, steam lines and flue gas lines.

This sensor integrates one of the worlds most trusted temperature transmitters, including the TTF300, TTH300 and TTH200 series, into the head to provide a repeatable and robust measurement.

Pressure transmitters
ABB's P-100, P-300 and P-500 series of pressure transmitters measure gauge, absolute or differential pressure. Differential pressure transmitters can be used to measure flow on DP primary elements, or level of process tanks or columns and can be fitted with or without diaphragm seals. These transmitters are capable of simultaneous measurement of differential pressure, absolute pressure and process temperature, and have an optional in-build flow computer for a four in one solution. Gauge pressure transmitters are used to precisely measure pressure in the absorber column and regenerator, for amine and CO2 lines, for heat exchangers, for steam and for filters.

Gas analysers
ABB modular continuous gas analysers series Advance Optima and EasyLine offer robust and reliable performance for gas concentration measurements in numerous applications, combining up to four analyser modules in one housing to measure up to five different gases continuously. This could include the Uras26 infrared photometer, the Limas21or Limas23 ultraviolet photometer, or the LS25 tunable diode laser absorption spectrometer.

ABB's hot/wet extractive analyser system ACF5000 with FTIR gas analyser, if required combined with FID and zirconia Oxygen sensor. ACF5000 can measure up to 15 components simultaneously including water soluble components to accurately monitor the composition of exhaust gases up- or downstream the CO2 absorber.

ABB's Sensi+ / GLA533 Single analyser device for continuous, simultaneous measurements of H2S, H2O and O2 contaminants in captured CO2.

PGC5000 and PGC1000 families of process gas chromatographs perform real-time analysis of the chemical composition of a process sample or stream, offering a solution to measure the most important components of the captured CO2 stream.

ABB FT-NIR spectrometer model MB3600 mounted with an InAs detector for use in a laboratory. Mend to quantify the CO2 loading and the concentration of amine in aqueous solution during the operation of a CCS pilot plant. Samples can be taken from three streams on the plant: the lean stream into the absorber, the rich stream out of the absorber and the lean stream from the stripper tower. Besides the CO2 loading and amine concentration, it is also possible to measure other components which age the absorbing solution.

Talys with fibre optic cables and inline measuring cell can perform the same tasks but this makes the measurements continuously and in line. Via Ethernet interface, the measurements from the Talys can be send to the DCS system for control purposes.

Flow computers (Flow-X)
The purpose of a CO2 flow metering system is to report the net CO2 quantity within the applicable OIML accuracy class, e.g. 1.5%. The Flow-X flow computer is certified for legal metrology of gas and liquid quantities and connects to flow meters, temperature, pressure and density transmitters, and to continuous gas analysers and chromatographs, to calculate net quantities following API, AGA, ISO and OIML conventions.

For mass flow meters the net CO2 quantity is directly calculated from the mass flow and the compositional analysis. For other flow meters, the density needs to be determined as well. Typically, the density is calculated by the flow computer with an Equation-Of-State (EOS) based on the measured pressure, temperature and the compositional analysis. For many CO2 applications the GERG-2008 EOS, that was originally developed for natural gas applications, provides adequate accuracy also in the dense (supercritical) phase. In the last decade improvements of GERG-2008, known as EOS-CG, have been developed to also cover CCUS applications with a significant water content and at elevated pressure and temperature conditions.

Level measurement
ABB's LMT100 and LMT200 magnetostrictive level transmitters enable level measurement of liquid CO2 in low pressure cryogenic containers, which is an essential but non-trivial task for liquid CO2 storage along the distribution supply chain. LMT100 and LMT200 series are also indicated for all level measurements of CO2 capture plants, including the absorber column and the regeneration unit.

Valve Positioner
The PositionMaster EDP300 is an electronically configurable positioner with communication capabilities, designed for mounting on pneumatic linear or part-turn actuators. It features a compact design, modular construction, and an excellent cost-performance ratio. Fully automatic determination of the control parameters and adaptation to the actuator allow for considerable time savings as well as optimum control behaviour.

pH analysers
Accurate measurement of pH is a key requirement across a multitude of industrial process control applications including carbon capture. In each instance, it is vital to make sure the right type of pH sensor is selected to ensure the best levels of performance, accuracy and reliability are achieved.

Our next generation range of pH sensors bring together over 70 years of ABB pioneering pH sensor development and application expertise with the latest advanced digital technology and sensor diagnostics. Part of the next generation of ABB's pH/ORP sensors, the 500 PRO series features the ultimate combination of performance, functionality and durability delivering outstanding performance for harsh/challenging industrial applications.

The 500 PRO features ABB's advanced tertiary cellular junction matrix designed to offer exceptional performance in harsh chemical applications. This unique approach ensures an arduous pathway for poisoning elements whiles ion-traps inhibit poisoning elements from reaching the reference electrode; helping extend the life of the sensor, without compromising performance.

ABB Ability
ABB Ability solutions combine ABB's deep domain expertise with connectivity and software innovation to empower real-time, data-driven decisions for safer, smarter operations that maximize resource efficiency and contribute to a low-carbon future. Our large portfolio of digital solutions helps organizations automate, optimize and future-proof their processes to achieve new heights of performance and drive sustainable progress.

One great example is the ABB Ability™ SRV500 Verification for measurement devices. It is an extensible application that connects with field devices over their applicable protocols to provide in situ verification. It provides PASS / FAIL results together with relevant diagnostic information to a series of tests chosen by the user and run on a field device and issues a test certificate as proof of verification. The best possible check of measurement performance, without removal from the process.

ABB Ltd.
Affolternstrasse 44
8050 Zurich
Switzerland

abb.com/measurement

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