

Key Performance Advantages

- Helps remove unwanted gases, or mercaptans, from fluid streams
- Performs as suitable amine for use in forming effective absorption media
- Exhibits applicable boiling point and vapor pressure

Oil & Gas

MMAMP[™]

Mono-Methyl 2-Amino-2-Methyl-1-Propanol Amine Component of Absorption Medium for Acid Gas Removal Applications from Fluid Streams

The value of natural gas can be directly connected to its purity. MMAMP[™], the new developmental additive for acid gas removal, will aid in providing customers the ability to effectively separate unwanted contaminants or agents from fluid streams in the critical capture and production phases of this natural resource.

Absorption Media Criteria

The removal of acid gases such as CO₂, H₂S, SO₂, SO₃, CS₂, HCN, COS or mercaptans, from fluid streams, such as natural gas, refinery gas, synthesis gas, coke furnace gas, coal gasification gas, recirculated gas, landfill gases, flue gas, combustion gases, liquefied petroleum gas (LPG) or natural gas liquids (NGL) is frequently made using aqueous solutions of organic bases (amines) as absorption media.

Generally, the absorption medium comprises 15 to 70% by weight of an amine or a combination of amines. Currently in the market, there is no amine that meets all the criteria:

- High acid gas absorption capacity and rate
- Low heat of absorption/desorption
- Non-corrosive
- Thermally stable
- Low vapor pressure
- Low hydrocarbons absorption
- Gas selectivity
- Solubility

Suitable Amines

Different chemicals are mixed to form the absorption medium in order to combine specific advantages of each. Suitable amines are distinguished commonly by a boiling point at atmospheric pressure of at least 120° C. Preferably, the amines have a vapor pressure at 20° C of no more than 0.02 bar absolute.

The suitable amines include, in particular:

- Alkanolamines such as:
 - Monoethanolamine (MEA)
 - Diethanolamine (DEA)
 - Diisopropanolamine (DIPA)
 - Triethanolamine (TEA)
 - Methyldiethanolamine (MDEA)
 - Dimethylethanolamine (DMEA)
 - Diethylethanolamine (DEEA)
 - 2-amino-2-methyl-1-propanol (AMP)
 - 2-amino-1-butanol (2-AB)
 - N,N-dimethyl-2-amino-2-methyl-1-propanol (DMAMP)
- Aminoethers such as:
 - 2-(2-aminoethoxy)ethanol (AEE)
 - 2-(2-tertbutylaminoethoxy)ethanol (TBAAE)
- Bistertiary diamines such as:
 - N,N,N',N'-tetramethylethylenediamine
 - N,N-diethyl-N',N'-dimethylethylenediamine
 - N,N,N',N'-tetraethylethylenediamine
 - N,N,N',N'-tetramethyl-1,3-propanediamine (TMPDA)
 - N,N,N',N'-tetraethyl-1,3-propanediamine (TEPDA)
- Cycloaliphatic amines such as:
 - cyclohexylmethyldimethylamine
- And mixtures thereof

In addition, the absorption medium often comprises at least one activator. The activator is customarily a primary or secondary amine and accelerates the carbon dioxide uptake by intermediate formation of a carbamate structure. The activator is preferably selected from: 5-, 6-, 7-membered saturated heterocycles having at least one NH group in the ring, which can comprise in the ring one or two further heteroatoms selected from nitrogen and oxygen such as:

- Piperazine
- 2-methylpiperazine
- N-methylpiperazine
- N-ethylpiperazine
- N-aminoethylpiperazine
- Homopiperazine
- Piperidine
- Morpholine

Plus primary or secondary alkanolamines such as MEA, DEA, DIPA, 2-AB, etc., in addition to alkylenediamines, polyalkylenepolyamines, etc.

The absorption medium can, in addition, comprise physical solvents which, for example, are selected from cyclotetramethylenesulfone and derivatives, aliphatic acid amides, N-alkylated pyrrolidones and corresponding piperidones, propylene carbonate, methanol, dialkyl ethers of polyethylene glycols and mixtures thereof. The absorption medium can comprise further functional components such as stabilizers, in particular antioxidants, corrosive inhibitors, etc.

Devices suitable for carrying out the acid gas removal process comprise at least one scrubbing column. The gas stream is generally fed into the lower region of the column and the absorption medium into the upper region of the column. The temperature of the absorption medium is generally, in the absorption step, about 20 to 100° C. The partial pressure of the carbon dioxide in the feed gas is in the range from about 1 to about 1000 psia. The loaded absorption medium is heated to 50-170° C at pressure ranging from about 1 to about 50 psia for regeneration, and the carbon dioxide liberated is separated off in a desorption column.

Sterically Hindered Amine Usage

The use of sterically hindered amines for CO₂ capture was proposed by Sartori and Savage⁽¹⁾. They showed that sterically hindered amines can have unique capacity and rate advantages in CO₂ sorption process. A limited number of processes using sterically hindered amines as alternatives to MEA, DEA and TEA are used commercially for CO₂ capture. Examples include the KS-1TM Process from Mitsubishi Heavy Industries and Kansai Electric Power Co., and the ExxonMobil FLEXSORB[®] process (which uses sterically hindered amine(s) for selective H₂S separation). AMP has been used as a hindered amine component of absorption mediums for acid gas removal applications. However, it has been demonstrated that ~4 M solution of AMP in the presence of 0.1 bar of CO₂ can start to precipitate at around 30° C, as shown in U.S. Patent No. 2014/0178278 A1⁽²⁾. To expand the utility of AMP to higher concentrations without precipitation, formulation with other components has been demonstrated⁽³⁾.

ANGUS and others have demonstrated that hindered amines based on N-alkyl-2-amino-2-methyl-1-propanols can be used as a suitable amine component of absorption medium for acid gas removal applications⁽⁴⁻¹⁰⁾. In at least one case as shown in U.S. Patent No. 2014/0178278 A1⁽²⁾ the precipitation of the amine-carbonate salt can be suppressed expanding the utility of these amines at high concentrations and pressures. ANGUS has demonstrated that MMAMP, as a drop-in replacement for MEA, can allow a 52% increase of CO₂ absorbed, all else being equal. Also, an 18% average decrease of heat of absorption per mole of CO₂ is observed. These show a clear advantage of CO₂ absorption capacity and energy requirements of MMAMP versus MEA.

An in-depth analysis on the topic can be found in an article recently published in *Energy & Fuels* entitled *CO₂ Reaction Mechanisms with Hindered Alkanolamines: Control and Promotion of Reaction Pathways*.

MMAMP Advantages vs. MEA

Amine solution used [*]	% Increase of CO ₂ moles/min absorbed ^{**}	% Average decrease of heat of absorption per mole of CO ₂ ^{**}
32.5% AMP [®] solution	30	7
32.5% MMAMP [™] solution	28	22
50% MMAMP [™] solution	52	18

*Compare to 32.5% MEA solution

**Assuming the same absorber column and stripper column, as well as the same volumetric amine solution flow rate for each solvent, and a CO₂ absorption capacity more commonly experienced in industry, taking into account corrosion and absorption rate limitations.

Product Stewardship

ANGUS encourages its customers to review their applications of ANGUS products from the standpoint of human health and environmental quality. To help ensure that ANGUS products are not used in ways for which they are not intended, ANGUS personnel will assist customers in dealing with environmental and product safety considerations. For assistance, product Safety Data Sheets, or other information, please contact your ANGUS representative at the numbers provided in this document. When considering the use of any ANGUS product in a particular application, review the latest safety data sheet to ensure that the intended use is within the scope of approved uses and can be accomplished safely. Before handling any of the products, obtain available product safety information including the safety data sheet(s) and take the necessary steps to ensure safety of use.

MMAMP Suitability as a Purification Agent

To summarize, as a suitable amine component of absorption medium for acid gas removal applications, MMAMP can be used to help in the effective capture, processing and purification of natural gas.

1. Sartori G. and Savage D.W., "Sterically Hindered Amines for CO₂ Removal from Gases". *Ind. Eng. Chem. Fundam.*, 1983, 22, 239-249.
2. U.S. 2014/0178278A1, ExxonMobil Research and Engineering Company, "CO₂ Capture via Amine-CO₂ Product Phase Separation".
3. WO 2015/188034 A1, Phillips 66 Company, "Novel Amine Solvent Blends".
4. EP 0705637B1, The Kansai Electric Power Co., Inc., "Process for Removing Carbon Dioxide from Gases".
5. Gangarapu S., Marcellis A.T.M. and Zuilhof H., "Carbamate Stabilities of Sterically Hindered Amines from Quantum Chemical Methods: Relevance for CO₂ Capture". *Chem. Phys. Chem.*, 2013, 14, 3936-3943.
6. Chowdhury F.A., Yamada H., Higashii T., Goto K. and Onoda M., "CO₂ Capture by Tertiary Amine Absorbents: A Performance Comparison Study". *Ind. Eng. Chem. Res.*, 2013, 52, 8323-8331.
7. U.S. Pat 8,419,831 B2, Research Institute of Innovative Technology for the Earth, "Method for Efficiently Recovering Carbon Dioxide in Gas".
8. U.S. 8920544B2, ThyssenKrupp Uhde GmbH, "Removal of Carbon Dioxide from Gases by Aqueous Amine Solutions Containing a Sterically Hindered Amine".
9. JP 2006240966A2, Research Institute of Innovative Technology for the Earth, "Method for Recovering Carbon Dioxide in Exhaust Gas by Absorption and Releasing".
10. GB 1058304A, Shell Int. Research, "Process for the Purification of Fluids".

Contact Information

angus.com

North America
+1-844-474-9969

Latin America
+55-11-4700-8427

Western Europe
+49-69-38-079-1799

Central and Eastern Europe
+49-69-38-079-1799

Middle East and Africa
+49-69-38-079-1799

Indian Subcontinent
+000-800-440-5098

Greater China
+86-40-0881-1243

Japan and Korea
+81-34-477-4961
+82-2-3483-6665

Southeast Asia, Australia and New Zealand
+66-2787-3335
+65-6723-1010

ANGUS[®]
CHEMICAL COMPANY

©[™]Trademark of ANGUS Chemical Company

Notice: No freedom from infringement of any patent owned by ANGUS or others is to be inferred. Because use conditions and applicable laws may differ from one location to another and may change with time, Customer is responsible for determining whether products and the information in this document are appropriate for Customer's use and for ensuring that Customer's workplace and disposal practices are in compliance with applicable laws and other government enactments. The product shown in this literature may not be available for sale and/or available in all geographies where ANGUS is represented. The claims made may not have been approved for use in all countries. ANGUS assumes no obligation or liability for the information in the document. References to "ANGUS" or the "Company" mean the ANGUS Chemical Company legal entity selling the products to Customer unless expressly noted. NO WARRANTIES ARE GIVEN: ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE ARE EXPRESSLY EXCLUDED.
Published May 2016 Form No. MMA-2176-0516-TGC