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# ALVIGO-MATROS CATALYSTS

## CONTENTS




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**MATROS TECHNOLOGIES, INC.** and **ALVIGO** has teamed up to offer a portfolio of high performance catalysts for the entire range of chemical processes involved in the production of ammonia, methanol, hydrogen, and syngas.

**Matros Technologies, Inc.** is a U.S. company established in 1993, is a supplier of catalysts as well as process engineering, R&D, and consulting services. Our team has been involved in academic and industrial R & D in the area of catalytic reactor technology for about 30 years, having pioneered the reversed-flow reactor (RFR) technology in the 70s.

Matros Technologies has been supplying catalysts, process solutions and engineering services for catalytic and thermal VOC oxidation, selective catalytic reduction of $NO_x$, synthesis of formaldehyde, and a number of other areas. The company's process design and optimization capabilities, including sophisticated catalyst testing equipment and process simulation software, help our customers to increase productivity and/or reduce costs.

**ALVIGO** operates primarily in post-Soviet countries, supplying catalysts and a full range of support and services related to catalysts and reactors used in the production of syngas, hydrogen, ammonia, and methanol. Its close ties with NIAP – a recognized scientific and technical leader in catalysis and process technology – ensures ready availability of highly qualified experts possessing knowledge, testing facilities, advanced instrumentation and software to help in solving even the most complicated problems.

With a foundation in decades long Russian scientific tradition, unparalleled knowledge of scientists and engineers, ISO 9001 compliant quality management system implemented at ALVIGO's manufacturing plants, excellent customer service, and total annual output of 6,000 tons, ALVIGO is able to meet the needs of the most demanding customers.

We offer catalysts for a wide range of processes including:

- sulfur removal by absorption,
- hydrodesulfurization,
- primary reforming,
- secondary reforming,
- high temperature shift reaction,
- low temperature shift reaction,
- methanation,
- ammonia synthesis,
- methanol synthesis.



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Combination of expertise and resources of both companies creates the capability to provide for consulting services and assistance in operation of ammonia, hydrogen or methanol plant.

Our scope of services includes:

## Catalyst Testing

Matros Technologies and Alvigo provide the customers access to a wide range of catalyst testing and characterization capabilities, including:

- Activity
- Surface science methods for in-depth look at the state of the catalyst surface
- Mechanical strength
- Chemical composition
- Surface area and other structural parameters

## Process Evaluation

Based on the catalyst test data, and using sophisticated process simulation software, we are able to determine optimum process conditions and to issue recommendations on complete or partial catalyst replacement.

We are ready to set up a service program aimed at evaluating the state of the catalyst in each of the process units using information about operating parameters measured by the plant.

## Lifetime Prediction

Using operating history of the catalyst, we can accurately forecast the expected catalyst life, and develop an optimum turnaround schedule.

## Catalyst Selection

Each process technology and plant is unique, and we work closely with customers to learn as much as possible about the process and equipment and to develop catalyst solutions tailored specifically for a given technology, equipment and operating conditions. We provide all information necessary for customer's personnel to take an informed decision on what catalyst would do the best job.

## Troubleshooting

Our team of highly qualified experts will be engaged whenever needed to solve customer's operating problems, both in our offices and the plant site.

## Plant Operator Training

We provide training courses for corporate and plant personnel of our customers, focused on our catalyst technology, properties, and operating conditions and guidelines.

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# 2. CATALYSTS

## 2.1. PURIFICATION OF GASES FROM SULFUR COMPOUNDS

Zn and Zn-Cu absorbents of **SPS-F** and **NIAP-02** series are designed for fine purification of natural, coke-oven and other process gases from sulfur compounds. The absorbents incorporate the results of extended research and development focused on a) development of superfine active zinc oxide, and b) formation of mechanically strong extruded particles with optimal pore structure that ensures superior dynamic characteristics and stability.

***SPS-FZ high efficiency ZnO absorbent***

### SPS SULFUR ABSORBENT SERIES

| | SPS-FZ | SPS-FP |
|---|---|---|
| **Appearance** | Light-gray cylinders | Dark-gray cylinders |
| **Chemical composition, %** | | |
| **ZnO** | 90 | 80 |
| **CuO** | - | 10 |
| **Bulk density, g/cm$^3$** | 1.3 | 1.3 |
| **Diameter, inch** | 5/32 – 15/64 (4 – 6 mm) | 5/32 – 15/64 (4 – 6 mm) |
| **Mechanical (crushing) strength, N** | 150 | 150 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 730 psig (5 MPa) |
| Temperature: | |
| SPS-FZ | 660 – 790 °F (350 - 420 °C) |
| SPS-FP | 480- 790 °F (250 - 420°C) |
| Space velocity | up to 1,700 h$^{-1}$, |
| $H_2S$ concentration | up to 50 ppm (80 mg/m$^3$) |



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Copper-promoted **SPS-FP** and **NIAP-02-03** absorbents provide for a reduction in operating temperature down to 480 °F (250 °C) while keeping the same or better desulfurization efficiency. They can effectively operate with reduced hydrogen feed, as well as remove organo-sulfur compounds.

***NIAP-02-03, copper-promoted low temperature ZnO absorbent***

## COPPER PROMOTED ABSORBENTS

| | NIAP-02-03 | NIAP-02-05 |
|---|---|---|
| **Appearance** | Light-green cylinders | Gray-white cylinders |
| **Chemical composition, %** | | |
| **ZnO** | 77 | 90 |
| **MgO** | 3.5 | 5 – 8 |
| **CuO** | 9 – 11 | - |
| **Bulk density, g/cm$^3$** | 1.4 | 1.2 |
| **Diameter, inch (mm)** | 9/64 – 7/32 (3.5 – 5.5) | 9/64 – 7/32 (3.5 – 5.5) |
| **Mechanical (crushing) strength, N** | 170 | 170 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 600 psig (4 MPa) |
| Temperature | 480 – 660 °F (250 - 350 °C), |
| Space velocity | 700 – 1,300 h$^{-1}$, |
| Hydrogen sulfide concentration | up to 50 ppm (80 mg/m3), |
| Hydrogen concentration | 4 – 11 % vol. |

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# 2.2. HYDRODESULFURIZATION

Al-Co-Mo and Al-Ni-Mo catalysts of **GPS** and **NIAP-01** series are used for hydrogenation of sulfur compounds found in natural gas and refinery gases used as feedstocks for ammonia, methanol and hydrogen production. The catalysts possess high efficiency while requiring low loadings, and operate effectively under conditions of drastic changes in sulfur content of the feedstock.

**GPS-1F** and **GPS-3Sh** are Al-Ni-Mo catalysts characterized by high hydrodesulfurization and hydrogenation activity and are recommended for use at higher content of nitrogen containing organic compounds, olefins and carbon oxides in the feedstock. **GPS-2F** and **GPS-4Sh** are Al-Co-Mo catalysts that provide for even higher than **GPS** types hydrodesulfurization activity.

## GPS HYDRODESULFURIZATION CATALYST SERIES

| | GPS-1F | GPS-2F | GPS-3Sh | GPS-4Sh |
|---|---|---|---|---|
| **Appearance** | Extruded cylinders | | Spheres | |
| **Chemical composition, %** | | | | |
| **$MoO_3$** | 8 – 12 | | 8 – 12 | |
| **NiO** | 2 – 3 | - | 2 – 3 | - |
| **CoO** | - | 2 – 3 | - | 2 – 3 |
| **Bulk density, g/cm$^3$** | 0.7 | | 0.8 | |
| **Diameter** | 5/64 – 9/64 (2.0 – 3.5 mm) | | 5/32 – 9/32 (4.0 – 7.0 mm) | |
| **Mechanical (crushing) strength, N** | 80 | 80 | 140 | 140 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 730 psig (5 MPa) |
| Temperature | 480 - 750 °F (250 - 400 °C), |
| Space velocity | up to 2,500 $h^{-1}$, |
| Inlet concentration of sulfur compounds | up to 25 ppm (40 mg/m3). |
| Added hydrogen concentration | 2 to 10 % vol. |

All **GPS** catalysts possess excellent mechanical strength and catalytic activity due to optimal, "egg-shell" type distribution of active components in the pellet, achieved at low content of active components.



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| | NIAP-01-01 | NIAP-01-03 |
|---|---|---|
| **Appearance** | Light-gray extrudates | |
| **Chemical composition, %** | | |
| **CoO** | 3.5 | - |
| **CoO or NiO** | - | 3.0 |
| **$MoO_3$** | 11 | 9.5 |
| **Bulk density, g/cm$^3$** | 0.8 | 0.8 |
| **Diameter, inch (mm)** | 9/64 – 7/32 (3.5 – 5.5) | 9/64 – 7/32 (3.5 – 5.5) |
| **Mechanical (crushing) strength, kg/mm** | 1.2 | 1.4 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 730 psig (5 MPa) |
| Temperature | 340 - 400 °C, |
| Space velocity | 500 – 2,000 $h^{-1}$, |
| Inlet concentration of sulfur compounds | up to 25 ppm (40 mg/m3). |
| Added hydrogen concentration | 2 to 10 % vol. |

***NIAP-01-01 cobalt containing hydrodesulphurization catalys is used in numerous ammonia plants***

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# 2.3. PRIMARY STEAM REFORMING

Choice of an optimum catalyst depends on many factors, such as furnace design, type of feedstock, steam to carbon ratio, etc. Therefore, we offer several types of catalysts that feature different carriers, shapes and chemical compositions.

**NIAP-18**, **NIAP-03-01**, **K-905-D1**, and **K-87-3** incorporate promoted nickel oxide deposited on refractory porous support. They are produced for steam and steam/carbon dioxide conversion of gaseous and liquid hydrocarbons in multitubular reformer furnaces.

***NIAP-18 primary reforming catalyst used in ammonia and methanol plants for reforming of natural gas or other hydrogen-rich feedstocks***

## PRIMARY REFORMING CATALYST NIAP-18

| | NIAP-18 |
|---|---|
| **Appearance** | Gray or light-gray cylindrical pellets |
| **Chemical composition, %** | |
| **NiO** | 10 -12 |
| **Bulk density, g/cm$^3$** | 1.0 |
| **Size, inches** | 9/16 x 15/32 x ¼ (14.5 × 12 × 6.5 mm) |
| **Mechanical (crushing) strength, N** | 500 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 500 MPa |
| Furnace outlet temperature | 1380 – 1560 °F (750 - 850 °C), |
| Space velocity | 1,500 – 1,800 h$^{-1}$, |
| Steam : gas ratio | 2.9 – 4.0 |



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# NIAP-03-01

Optimized pellet shape and size of this catalyst provides for:

- high specific activity of the catalyst bed due to increased surface of the granules and their stability during operation;
- high bed porosity and low pressure drop;
- lower tube wall temperature due to improvement of radial heat exchange within the tubes;
- perfect flowability of catalyst granules, which increases packing density.

The improved catalyst pore structure provides:

- increase of catalyst activity and catalyst life time;
- increase of thermal stability of active component.

These advantages allow for extending the service life of catalyst and tubes, increased productivity of the furnace, and decreased energy consumption.

**NIAP-03-01** has high thermal stability, and withstands more than 20 thermal shocks (1,000 °C - air) without crushing. The catalyst does not contain silicon, thus eliminating problems related to its migration.

## PRIMARY REFORMING CATALYST NIAP-03-0

| | NIAP-03-01 |
|---|---|
| **Appearance** | Gray or light-gray cylinders with 7 holes |
| **Chemical composition, %** | |
| **NiO** | 11 |
| **Bulk density, g/cm$^3$** | 1.0 |
| **Size, inches** | 5/6 x (7) 1/8 x 35/64 (16.5 × (7)3 x 14) |
| **Mechanical (crushing) strength, N** | 500 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 580 psig (4.0 MPa) |
| Furnace outlet temperature | 1380 – 1560 °F (750 - 850 °C), |
| Space velocity | up to 2,000 h$^{-1}$, |
| Steam : gas ratio | 2.9 – 4.0 |

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Promoted by lanthanum, **K-905-D1** and **K-87-3** catalysts are highly resistant to coke formation in primary reformers.

| | K-905-D1 | K-87-3 |
|---|---|---|
| **Appearance** | Gray Rashig rings | Gray cylinders |
| **Chemical composition, %** | | |
| **NiO** | 10 – 12 | 10 – 12 |
| **Promoters** | 3 | 3 |
| **$Al_3O_3$** | Balance | balance |
| **Bulk density, g/cm$^3$** | 1.0 | 1.2 |
| **Size, inches** | 5/8 x 5/8 x 15/64 (16 × 16 × 6 mm) * | 19/32 x 19/32 (15 × 15 mm) |
| **Mechanical (crushing) strength, N** | 750 | 750 |

*Depending on the reformer design, other sizes are available

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 580 psig (4.0 MPa) |
| Furnace outlet temperature | 1,650 °F (900 °C), |
| Space velocity | up to 2,000 h$^{-1}$, |
| Steam : gas ratio | 2.9 – 5.0 |

## 2.4. SECONDARY REFORMING

Nickel catalysts NIAP-03-01, NIAP-20, NIAP-20-01, K-905-D2, NIAP-22V, GIAP-3-6H, GIAP-8S, and GIAP-14S are used in autothermal and secondary reforming processes.

While designed for primary reforming process, **NIAP-03-01** catalyst can be used for secondary reforming, especially in larger ammonia plants, (1,700 TPD or more). Due to high activity of the catalyst, reduced loading is required. An increase in free space above the catalyst bed allows for prevention of local overheating of the catalyst in the upper part of converter.

**NIAP-20-01**, **NIAP-20** and **K-905-D2** catalysts are offered as mainstream catalysts for secondary reforming process. The products ensure high productivity, low pressure drop, and long operational life in shaft converters of large plants.

Sometimes, it is recommended to combine **NIAP-20**, **NIAP-20-01**, **K-905-D2** and **NIAP- 03-01**.



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## NIAP SECONDARY REFORMING CATALYSTS SERIES

| | NIAP-20 | NIAP-20-01 |
|---|---|---|
| **Appearance** | Gray or light gray Rashig rings | |
| **Chemical composition, %** | | |
| **NiO** | 8 | 11 |
| **CaO** | 8 – 10 | 8 – 10 |
| **$Al_3O_3$** | Balance | balance |
| **Bulk density, g/cm$^3$** | 1.0 | 1.2 |
| **Size, inches** | 49/64 x 9/16 x 11/32 (19.5 × 14. × 8.5 mm) | 9/16 x 15/32 x 1/4 (14.5 × 12 × 6.5 mm) |
| **Mechanical (crushing) strength, N** | 500 | 500 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 500 psig (3.5 MPa) |
| Furnace outlet temperature | 1740 – 1830 °F (950 - 1,000 °C), |
| Space velocity | 1,000 – 1,300 h$^{-1}$, |
| Air : gas ratio | 1.43 – 1.44 |

When there are no strict requirements to pressure drop, conventional nickel catalysts for secondary reforming **GIAP-3-6N**, **GIAP-8S** and a protective layer of Al-Cr catalyst **GIAP-14S** are offered.

**NIAP-22V**, which does not contain chrome is preferable for use in the protective layer.

Depending on requirements of plant operation and the composition of converted gas, we propose optimized, combined catalysts loadings that provide for minimal pressure drop over catalysts bed with the lowest methane content at the outlet.

***NIAP-20, a secondary reforming catalyst applied in ammonia units with production rate up to 2,000 stpd (1,800 mtpd)***

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*K-905-D2 highly active secondary reforming catalyst applied both as main catalyst bed charge and guard bed*

## SECONDARY REFORMING CATALYST K-905-D2

| | K-905D-2 |
|---|---|
| **Appearance** | Gray Rashig rings |
| **Chemical composition, %** | |
| **NiO** | 8 – 10 |
| **Bulk density, g/cm$^3$** | 1.0 |
| **Size, inches** | 5/8 x 5/8 x 15/64 (16 × 16 × 6 mm) * |
| **Mechanical (crushing) strength, N** | 500 |

*Depending on the reformer design, other sizes are available

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 500 psig (3.5 MPa) |
| Furnace outlet temperature | 1,740 – 1,830 °F (950 - 1,000 °C), |
| Space velocity | 1,000 – 1,300 h$^{-1}$, |
| Air : gas ratio | 1.43 – 1.44 |

## GIAP SECONDARY REFORMING GUARD BED CATALYST SERIES

| | GIAP-3-6N | GIAP-8S |
|---|---|---|
| **Appearance** | Gray rings | Gray cylinders |
| **Chemical composition, %** | | |
| **NiO** | 6 – 9 | 6 – 10 |
| **$Al_3O_3$** | balance | Balance |
| **Bulk density, g/cm$^3$** | 1.4 | 1.2 |
| **Size, inches** | 19/32 x 19/32 x 5/32 (15 × 15 × 4 mm) | 19/32 x 19/32 (15 x 15 mm) |
| **Mechanical (crushing) strength, N** | 750 | 750 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 580 psig (4 MPa) |
| Temperature | up to 2,200 °F (1,200 °C), |
| Space velocity | up to 4,000 h$^{-1}$ |



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## HIGHLY STABLE SECONDARY REFORMING GUARD BED CATALYST GIAP-14S

| | GIAP-14S |
|---|---|
| **Appearance** | Grey-green cylinders |
| **Chemical composition, %** | |
| **$Cr_2O_3$** | 5 – 8 |
| **$Al_2O_3$** | Balance |
| **Bulk density, g/cm$^3$** | 1.2 |
| **Size, inches** | 19/32 x 19/32 (15 × 15 mm) |
| **Mechanical (crushing) strength, N** | 600 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 580 psig (4 MPa) |
| Temperature | up to 2,300 °F (1,250 °C), |

## CHROMIUM-FREE SECONDARY REFORMING GUARD BED CATALYST NIAP-22V

| | NIAP-22V |
|---|---|
| **Appearance** | Cylinders with 6 holes and convex butts |
| **Chemical composition, %** | |
| **NiO** | 6 – 8 |
| **$Al_2O_3$** | Balance |
| **Bulk density, g/cm$^3$** | 1.0 |
| **Size, inches** | 1–3/16 x 1–3/16 (30 × 30 mm) |
| **Mechanical (crushing) strength, N** | 800 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 580 psig (4 MPa) |
| Temperature | up to 2,300 °F (1,250 °C) |

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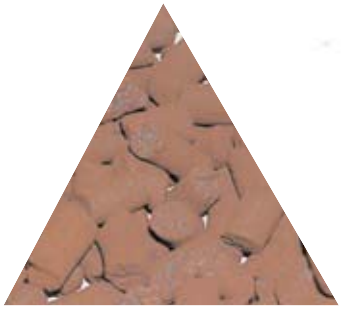
# 2.5. HIGH TEMPERATURE CO CONVERSION

Four types of catalysts are produced for high temperature CO steam conversion (High Temperature Shift). The catalysts differ in shape, pellet size, and chemical composition. Along with conventional **STK-1**, promoted **STK-SF**, Fe-Cr **STK-SMT** and **STK-SMF** are offered, that do not need desulfurization. The catalysts have high activity due to promotion by copper, can operate at low temperatures, low steam : gas ratio, decreased catalysts loads. The choice of catalyst depends on particular features of the plant.

STK and STK-SMF are designed for operation in ammonia plants at lower inlet temperatures of 595 – 615 °F (314 – 325 °C) while STK-SF is used at inlet temperature of 615 – 645 °F (325 – 340 °C).



***STK-SMF, highly active extruded HTS catalyst features low sulfur start-up emission, high mechanical strength and low bed shrinkage***

## STK HIGH TEMPERATURE SHIFT CATALYST SERIES

| | STK-SMT | STK-SMF | STK-1 | STK-SF |
|---|---|---|---|---|
| **Appearance** | Tablets | Extruded cylinders | | |
| **Chemical composition, %** | | | | |
| **$Fe_2O_3$** | 96 | 99 | 92 | 88 |
| **$Cr_2O_3$** | 8 | 8 | 8 | 8 |
| **CuO** | 2 | 2 | - | - |
| **Promoters** | - | - | - | 4 |
| **Bulk density, g/cm$^3$** | 1.2 | 1.3 | 1.3 | 1.3 |
| **Size, inches** | 11/32 x 15/64 or 15/64 x 13/64 (9 × 6 or 6 × 5 mm) | Diameter 13/64 or 9/32 (Diameter 5 or 7 mm) | | |
| **Mechanical (crushing) strength, N** | 300 or 200 | 200 or 300 | | |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 580 psig (4 MPa) |
| Temperature | 600- 930 °F (315 - 500 °C), |
| Space velocity | up to 4,000 h$^{-1}$, |
| Steam : gas ratio | 0.4 – 0.8 |



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# 2.6. LOW TEMPERATURE CO CONVERSION

**SNK- 2** is a Cu-Zn-Al co-precipitated catalyst for low temperature shift, having high activity and providing for minimal methanol formation.

**NIAP-06** catalysts comprise copper, zinc and aluminum compounds with addition of a special cement that adds strength to catalyst pellets after hydrothermal hardening.

**NIAP-06-04** is designed for use in the primary bed, while **NIAP-06-03** is loaded in the front layer to protect primary catalyst from destruction caused by moisture condensation and from sulfur poisoning.

*Tabletted low methanol LTS catalyst SNK-2 featuring high activity and selectivity*

*Extruded LTS catalyst NIAP-06-04 promoted with special high purity cements to provide for highest activity and mechanical strength*

## LOW TEMPERATURE SHIFT CATALYST SNK-2

| | SNK-2 |
|---|---|
| **Appearance** | Black cylinders or tablets |
| **Chemical composition, %** | |
| **CuO** | 43 |
| **ZnO** | 43 |
| **$Al_2O_3$** | 11 |
| **Bulk density, g/cm$^3$** | 1.3 |
| **Size, inches (mm)** | 15/64 x 5/32 (6 × 4 mm) or 13/64 x 13/64 (5 × 5 mm) |
| **Mechanical (crushing) strength, N** | 130 |

**Operating conditions:**

| | |
|---|---|
| Pressure | up to 580 psig (4 MPa) |
| Temperature | 360 – 570 °F (180 - 300 °C), |
| Space velocity | up to 5,000 h$^{-1}$, |
| Steam : gas ratio | 0.4 – 0.8 |

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## NIAP LOW TEMPERATURE SHIFT CATALYSTS SERIES

| | NIAP-06-03 | | NIAP-06-04 | |
|---|---|---|---|---|
| **Appearance** | Dark gray to light green cylindrical pellets | | | |
| **Chemical composition, %** | | | | |
| **CuO** | 23 – 31 | | 45 – 51 | |
| **ZnO** | 36 – 44 | | 20 – 25 | |
| **$Al_2O_3$** | 19 | | 17 | |
| **CaO** | 5 – 11 | | 4 – 10 | |
| **Bulk density, g/cm$^3$** | 1.2 | | 1.2 | |
| **Size, inches (mm)** | 13/64 (5.0) | 9/64 (3.5) | 13/64 (5.0) | 9/64 (3.5) |
| **Mechanical (crushing) strength, N** | 1.7 | 1.5 | 1.7 | 1.5 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 540 psig (3 MPa) |
| Temperature | |
| NIAP-06-03: | 390 – 680 °F (200 – 360 °C) |
| NIAP-06-04: | 365 – 680 °F (185 – 360 °C) |
| Space velocity | 2,000 – 5,000 $h^{-1}$, |
| Steam : gas ratio | 0.4 – 0.8 |
| Impurities, mo more than: | |
| sulfur | 0.15 ppm (0.2 mg/m$^3$) |
| chlorine | 0.03 ppm (0.05 mg/m$^3$) |
| Inlet CO concentration | 2 – 5 % vol |



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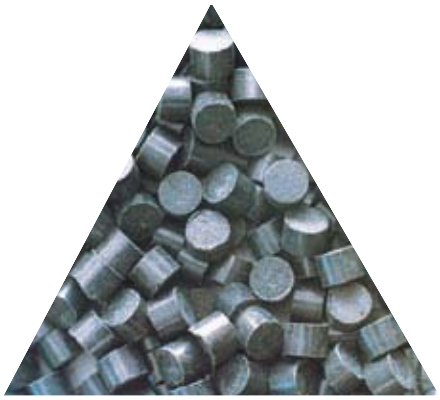
# 2.7. METHANATION

Nickel catalysts **NIAP-07-01**, **NIAP-07-02**, **TO-2M** are used for purification of hydrogen containing gases from carbon oxides by via hydrogenation to methane. Nickel content varies between 30 and 40% as NiO. These catalysts are the most active and reliable due to higher content of superfine nickel per unit volume. The catalysts withstand short-term overheating up to 550°C (**NIAP-07-02 -** up to 650°C) without activity loss, and ensure stable pressure drop throughout the entire lifetime.

If there is a need in purification from carbon oxides at low temperatures (150 °C at the outlet), ruthenium catalyst **RKM-3** catalyst is used.



***NIAP-07-02, a methanation catalyst providing increased temperature resistance and as long as 20 years lifetime***

## METHANATION CATALYSTS

| | NIAP-07-01 | NIAP-07-02 | TO-2M |
|---|---|---|---|
| **Appearance (all are cylindrical tablets)** | taupe to black | taupe to black | dark-brown |
| **NiO content, %** | 33-39 | 32-38 | 35-41 |
| **Bulk density, g/cm$^3$** | 1.2 | 1.15 | 1.25 |
| **Size, inches** | 7/32 x 11/64 (5.5 × 4.5 mm) | 7/32 x 3/8 (5.5 × 5.0 mm) | 7/32 x 3/8 (5.5 × 5.0 mm) |
| **Mechanical (crushing) strength, N** | 70 | 100 | 100 |
| **Operating conditions:** | | | |
| **Pressure, psig** | 290 – 4,000 (2 - 30 MPa) | 290 – 4,000 (2 - 30 MPa) | 15 – 4000 (0.1 – 30 MPa) |
| **Inlet $CO_x$ concentration, % vol.** | 0.3 – 1.3 | 0.3 – 2.5 | < 2 |
| **Temperature, °F** | 355 – 840 (180 – 450 °C) | | |
| **Space velocity, h$^{-1}$** | 3,000 – 20,000 | | |

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### LOW TEMPERATURE METHANATION CATALYST RKM-3

| | RKM-3 |
|---|---|
| **Appearance** | Taupe or black pellets |
| **Ru content, %** | 0.3 |
| **Bulk density, g/cm$^3$** | 0.9 |
| **Diameter, inches** | 3/32 – 1/8 (2.6 – 3.0 mm) |
| **Mechanical (crushing) strength, N** | 120 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 4,400 psig (30 MPa) |
| Temperature | 300 °F (150 °C), |
| Space velocity | 3,000 – 20,000 h$^{-1}$, |
| Inlet $CO_x$ concentration | up to 3 % vol. |

## 2.8. AMMONIA SYNTHESIS

**SA-S** is our catalyst for ammonia production from nitrogen/hydrogen mixture. It is made of magnetite with an optimum mix of promoters. The catalyst can be supplied in pre-reduced form (**SA-SV**) and of various sizes: fine grain fractions (1.5 – 3 and 3 – 5 mm), coarse grain fractions (5 – 7, 7 – 10, and 10 – 15 mm).

The catalyst is prepared from a special, high purity raw material. The pressure drop through the catalyst bed remains constant during its entire lifetime. The catalyst has high and stable activity and is safe, as confirmed by hundreds of loadings during over 30 years of commercial application.

***SA-S ammonia synthesis catalyst featuring uniform fraction size, high activity and long lifetime, has been applied in hundreds of ammonia plants.***



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### AMMONIA SYNTHESIS CATALYSTS

| | SA-S | SA-SV |
|---|---|---|
| **Appearance** | Irregular black or gray pellets | |
| **Chemical composition, %** | | |
| **$K_2O$** | 0.8 – 1.2 | |
| **$Al_2O_3$** | 2.4 – 3.8 | |
| **CaO** | 1.9 – 2.8 | |
| **$SiO_2$** | less than 0.7 | |
| **Fe metal** | - | 72 |
| **Fe oxides** | Balance | balance |
| **Bulk density, g/cm$^3$** | 2.2 | 2.2 |
| **Size fraction, inches** | 1/16 x 1/8, 1/8 x 3/16, 3/16 x 1/4, 1/4 x 3/8, 3/8 x 5/8 (1.5 x 3, 3 x 5, 5 x 7, 7 x 10, 10 x 15 mm) | |

**Operating conditions:**

| | |
|---|---|
| Pressure | 2,200 – 8,000 psig (15 – 55 MPa) |
| Temperature | 750 – 1,100 °F (400 - 600 °C), |
| Space velocity | 30,000 $h^{-1}$ |

## 2.9. SYNTHESIS OF METHANOL

***SNM-U, recently developed highly active and selective methanol synthesis catalyst, since 2000 has demonstrated excellent performance in 9 commercial converters***

**SMS-4** is a Zn-Cr catalyst, conventionally used for high temperature methanol synthesis from syngas. Small pellet size (tablets with diameter 5-6 mm) provides for reduced diffusion resistance and plant productivity increase by 5-10%.

**SNM-U** is a new generation Cu-Zn-Al catalyst, manufactured using nitrate precipitation technology. The catalyst has very high activity and thermal stability that ensures long lifetime. High selectivity of **SNM-U** allows for producing a very high quality raw methanol, with substantial savings of raw materials and energy. Improved mechanical strength of the catalyst tablets allows for longer service life without destruction or an increase in the pressure drop through the reactor.

## METHANOL SYNTHESIS CATALYST SMS-4

| | SMS-4 | | | |
|---|---|---|---|---|
| **Appearance** | Grey-yellow tablets | | | |
| **Chemical composition, %** | | | | |
| **ZnO** | 55 – 58 | | | |
| **$Cr_2O_3$** | 33 – 35 | | | |
| **Bulk density, g/cm$^3$** | 1.3 – 1.8 | | | |
| **Size, inches** | 11/32 x 5/16 (9 × 8 mm) | 11/32 x 3/16 (9 × 5 mm) | 9/32 x ¼ (7 × 6 mm) | 3/16 x 3/16 (5 × 5 mm) |
| **Mechanical (crushing) strength, N** | 200 | 150 | 150 | 120 |

**Operating conditions**:

| | |
|---|---|
| Pressure | over 2,900 psig (20 MPa) |
| Temperature | 610 – 750 °F (320 - 400 °C) |

## METHANOL SYNTHESIS CATALYST SNM-U

| | SNM-U |
|---|---|
| **Appearance** | Black tablets |
| **Chemical composition, %** | |
| **CuO** | 53 |
| **ZnO** | 26 |
| **$Al_2O_3$** | 5.5 |
| **Bulk density, g/cm$^3$** | 1.3 |
| **Size, inches** | 3/16 x 3/16 (5 × 5 mm) or 15/64 x 5/32 (6 × 4 mm) |
| **Mechanical (crushing) strength, N** | 130 |

**Operating conditions**:

| | |
|---|---|
| Pressure | up to 1,450 psig (10 MPa) |
| Temperature | 390 – 570 °F (200 - 300 °C) |



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