MRPL

Mangalore Refinery & Petrochemicals Ltd

(A subsidiary of Oil and Natural Gas Corporation Ltd)

EXPRESSION OF INTEREST (EOI)

For

Multipurpose Multireactor Pilot Unit at MRPL

EOI NO. : MRPL/2019/TS/EOI-MMPU/492

Mangalore Refinery and Petrochemicals Limited (MRPL) is a subsidiary of M/s Oil and Natural Gas Corporation Limited (ONGC).MRPL proposes to install Multipurpose Multireactor Pilot Unit (MMPU) at MRPL R & D.

EOI Details as follows

EOI No	MRPL/2019/TS/EOI-MMPU/492
EOI on Website	From 16.10.2019 To ~~26.11.2019~~ Extended till 31.12.2019
Closing date for submission of	Up to 17:00 Hrs. (IST) on ~~26.11.2019~~ 31.12.2019
EOI Documents available at	www.mrpl.co.on/eoi

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The envelope containing the document shall be superscribed **"Documents For Multipurpose Multireactor Pilot Unit (MMPU)"**.

MRPL

Multipurpose Multi-reactor Pilot Unit

Specifications for EOI

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1. **Background:**

1.1. MRPL is a Schedule "A" Central Public Sector Enterprise, operating a 15 MMTPA name plate capacity refinery with a nelson complexity factor of more than 9 at Mangalore, India.

1.2. The objective of this EOI is to gather cost, floor area requirements and feedback on the system design specifications from reputed vendors for the proposed Multipurpose Multi-reactor Pilot Unit (MMPU).

1.3. Scope includes design, engineering, fabrication, supply of MMPU along with training as per the scope of work and other aspects described in sections below.

2. **Pilot Reactor Objective & Configuration**

2.1. MMPU's is proposed to be operated for testing and evaluation of typical hydroprocessing and other catalyst portfolio at MRPL R&D. Apart from catalyst evaluation, the system is also intended for experiments that aid in optimization of commercial process units of MRPL.

2.2. Feed objectives: The system shall be capable of operating with the following feedstock:

2.2.1. Mineral Oil & mixtures: Vacuum Gas Oil, Gas Oil, Naphtha Mixed Gas Oil, Kerosene, Kerosene Mixed Gas Oil, Vegetable Oil, Vacuum Gas Oil, Vacuum Residue and the blends thereof.

2.2.2. Chemicals: Methanol, Ethane, Ethylene, Propane, Propylene, Butane, Butenes, Pentane, Pentenes, Cyclohexane, Benzene, Toluene, Xylene, Ethylbenzene, Isopropyl alcohol, DMDS, MDEA, DEA, CO_2, N_2, Helium etc.

2.2.3. Steam or water may also be used as co-feed for certain reactions.

2.2.4. The above feedstocks may or may not be hydroprocessed with H_2 gas as co-feed.

2.3. Two units of following configurations are desired:

2.3.1. Unit-1 consists of two reactor system which together shall be of any of the three volumes of neat catalyst or catalyst and inerts as depicted in table below for testing and evaluation. Based on supplier's information on cost, floor print area and pros & cons with each of the reactor capacities in Table below, MRPL may decide on one of the capacities for Unit-1 while tendering. This unit shall be typically used for high pressure hydro-cracking as well as for low pressure hydro-treating, catalyst tests, vapor phase hydrotreating, isomerization and alkylation reactions.

S.No	Reactor Definition	Capacity Required

1.	100 ml reactor	50ml-100 ml neat catalyst or 100 ml-200ml catalyst and inerts
2.	500 ml reactor	200 ml-500 ml neat catalyst or 400 ml-800ml catalyst and inerts
3.	950 ml reactor	500ml-950 ml neat catalyst or 700 ml-1500ml catalyst and inerts

2.3.2. Unit-2 consists of one reactor system which shall allow about 10 ml neat catalyst/ 20ml catalyst + inerts for testing and evaluation. This unit's purpose is for catalyst screening and proof of concepts of high pressure hydro-cracking, low pressure hydro-treating catalyst, vapor phase hydrotreating, isomerization and alkylation reactions.

2.4. The desired design configuration for unit-1 and unit-2 are depicted in the block flow diagrams attached herewith as Annexure-1 and Annexure-2 respectively.

2.5. Unit-1 shall pilot a typical hydroprocessing plant with two stage gas-liquid separators, recycle gas cleaning and recycle gas compressor, H_2S stripper, and a splitter or fractionator. Gas from the LP separator and/or stripper shall be routed to a scrubber or vent while fractionated liquid product shall be sent to sampling points followed by product/slop tanks.

2.6. Unit-2 shall be simplistic piloted version of the process wherein the 2 phase backpressure control (BPC) valve can be used in lieu of separators. For unit-2, BPC to be followed by low pressure separator or stripper. Gas from the LP separator or stripper shall be routed to a scrubber or vent while liquid product shall be directly sent to sampling points followed by product/slop tanks.

2.7. Reactors shall be bypassed as well as operated in up-or downflow-trickle mode for operations including but not limited to catalyst wetting during start-up wherein the bed shall be flooded in upflow mode before changing to trickle flow.

3. System Design Requirements

3.1. This section details the design requirement of unit-1 and unit-2 configurations along with other objectives mentioned in section 2 above.

3.2. Unless otherwise explicitly stated, the design aspects mentioned in the ensuing sections shall be applicable to both unit-1 and unit-2. System is general nomenclature followed for aspects applicable to both unit-1 and unit-2.

3.3. Overall system design requirements:

3.3.1. System's metallurgy shall be designed for wet H2S and hydrogen induced cracking at appropriate locations. The corrosion according to chemical compatibility tables is expected be beneath 0.11 mm/year with a high H2S & NH3 concentration

3.3.2. WHSV range of the reactors in the system shall vary between 0.5h-1 to 7 h-1

3.3.3. For hydroprocessing reactions Gas/Oil ratio range shall vary between 100 Nm3/ton to 350 Nm3/ton range for 99.9% pure hydrogen

3.3.4. All feed vessels shall be connected to each of the reactors with static mixer facility for co-mixing feeds and feeding

3.3.5. All gaseous feed shall also mix with liquid feed in a static mixer.

3.4. Overall Unit-1design requirements:

3.4.1. Two separators are envisaged and details are provided in clause 3.15 below.

3.4.2. WHSV range of the reactors in the system shall vary between 0.5 h^{-1} to 7 h^{-1}.

3.4.3. For hydroprocessing reactions Gas/Oil ratio range shall vary between 100 Nm^3/ton (to 350 Nm3/ton (short residue) range for 99.9% pure hydrogen.

3.4.4. Hydrogen rich gas from separators shall optionally be recycled after cleaning H2S.

3.4.5. Purity indicator and controller of the hydrogen to reactor to be added with a control valve.

3.4.6. Purity of fresh + recycled H_2 gas fed to reactors shall be controlled by manipulation of fresh H2 flow from cylinder control valve along with purging of impure gas from the separators.

3.4.7. The unit shall also be capable of by passing one or both the separators and operate H2 in once-through mode without recycle.

3.4.8. The fractionator reboiler shall be capable of reboiling up to 380°C.

3.4.9. Residue fraction or bottom fraction (unconverted oil) from product fractionator shall be optionally recycled to fresh feed and there shall be automatic control on the fresh feed to unconverted oil ratio while charging to the reactor.

3.5. Feed Vessel for both Unit-1 and Unit-2:

3.5.1. There shall be 2 tanks included with feed stations with pumps and flowmeters.

3.5.2. The vessel shall have heating facility to maintain the feedstock between 40° - 80°C

3.5.3. Feed from both the tank shall be dosed at the same time, so that blending is possible, addition of co-feeds or instant feed changes and evaluation on the catalyst performance and/or stability.

3.5.4. All vessels shall be nitrogen blanketed and shall have a bottom drain valve.

3.5.5. The vessels specification are as below:

- Material stainless-steel 316L
- 20L Volume minimum for Unit-1 and 2L Volume minimum for Unit-2
- Design Pressure of 3 Bar minimum
- Design Temperature of 200°C minimum
- Operating temperature: Ambient – 80°C
- Dip tube for liquid removal (to prevent particles if any)
- Nitrogen blanket connection
- Bottom connection with ball valve for liquid removal/cleaning
- Removable heating jacket
- Placed on a 35kg balance + 5kg overload and 0.1g accuracy for unit-1
- Placed on a 5kg balance + 0.5kg overload and 0.01g accuracy for unit-2

3.5.6. Atleast one of the vessels shall have capability to be used for activation of feed / pre-sulphiding with DMDS spiked feeds or others.

3.5.7. The connections to the tank shall be done with quick couplings for easy removal and exchange of the tank against another feed tank during feed change.

3.5.8. The vessels shall have a larger closure in the middle, which can be opened by hand when the vessel is depressurized. The feed is withdrawn from the vessel with a dip tube and shall not be from a bottom connection that particles and impurities are not withdrawn and remain in the vessel so that feed line filters are not getting plugged that fast and pumps can operate longer.

3.5.9. The oil feed vessel is weighed on a balance, which can weigh up to 35kg + 5kg overload with an accuracy of 0.1g.

3.5.10. The commercial or pricing offer shall include three number of vessels – two in-service and one as spare/standby.

3.6. <u>Liquid Feed Pump:</u>

3.6.1. MRPL prefers to have hydraulically actuated diaphragm metering pumps as feed pumps.

3.6.2. The pump shall be compatible for all the feed types indicated in the feed section above.

3.6.3. The pump shall have following features:

- Flow turn down: 500:1 minimum
- Operating temperature: 150°Cmax
- Discharge pressure: 500 barg max
- Leak-proof and odor tight
- All moving parts are continuously lubricated with oil. The pump shall be protected from weather and splash water.
- A pressure relief valve in the hydraulic part of the diaphragm pump to prevent potential overload situations. This valve shall be individually adjustable and can therefore be adapted to different operating situations.
- Superior metal diaphragm technology so as to enable discharge pressures up to 500 bar and meter flow precisely at an accuracy of ± 1%.
- The pumps shall be dry-run safe and maintenance friendly. No sliding seals or packages shall be inserted in view of process safety.

3.7. Mass flow meters for liquid feeds:

3.7.1. MRPL prefers to have two different MFCs for low temperature (naphtha, kero & diesel) and high temperature (VGO, SR & blends thereof).

3.7.2. High temperature MFCs specifications are as below:

- Accuracy: better than 0.1% of mass flow rate at flows >1g/min
- Dynamic turn down: 500:1
- Density accuracy: 0.001 g/cm³
- Material of construction: AISI 316L
- Internal PT100 measurement
- Operating temperature: 150°Cmax

3.7.3. Low temperature MFCs specifications are as below:

- Accuracy: better than 0.1% of mass flow rate at flows >0.1 g/min
- Dynamic turn down: 500:1
- Density accuracy: 0.001 g/cm³

- Operating temperature:70°C max

3.7.4. MFC's accuracy mentioned above are of paramount importance to MRPL and in order to honor the same, liquid feed can be considered to operate at recycle to compensate for high pressure drop across the MFC with only tap off to meet the required flow for dosing with the MFC device.

3.8. High-pressure Hydrogen Gas Supply:

3.8.1. Gas line design pressure is 300barg and maximum operating pressure is 250barg.

3.8.2. The main H_2 gas dosing line, from which the various reactors are tapping off the gas for dosing is equipped with the parts as listed below.

3.8.3. Automated high-pressure Shut-off valve (diaphragm valve)

3.8.4. Tee filter (413 bar design pressure)

3.8.5. Flow restriction orifice (Cv calculated in initial engineering phase; Physical limitation to the maximum flow that can enter the unit for safety reasons – flow capacity for relief valves shall be designed accordingly)

3.8.6. Check valve to prevent unidirectional flow

3.8.7. Manual high-pressure ball valve, on/off

3.8.8. Manual pressure reducing regulator

3.8.9. Mechanical Pressure gauges for displaying the line pressure

3.8.10. High-pressure relief valve

3.8.11. High pressure ball and needle valve for relieving the line pressure

3.9. Mass flow meters for H_2 gas:

3.9.1. Hydrogen shall be dosed with Mass Flow Controllers (MFC) capable of accurate gas dosage (better than 0.1% of mass flow rate at flows >0.1 g/min) up to 250 barg differential pressure.

3.9.2. The upstream pressure of the valve shall never have to be changed as a function of the downstream pressure. The MFCs shall not dictate manual adjustment of the upstream pressure during pressurization and depressurization of the unit so as to control accurately.

3.9.3. There shall not be any manual interaction when going raising the pressure from 0 bars to 250 bars.

3.9.4. The calibration of the MFC shall not have to be changed each time that a different process pressure is operated at.

3.9.5. MFCs shall have a dynamic turn down of 500:1

3.10. <u>Nitrogen Gas Supply:</u>

3.10.1. Nitrogen Gas shall be supplied from high-pressure gas cylinders and used for high-pressure dosing/pressure testing etc.

3.10.2. The general design and the components shall be analogous to the hydrogen supply line as mentioned in Clause 3.6 above.

3.10.3. Nitrogen shall be utilized for pressurizing the liquid feed tanks and also the product tanks in case liquid shall be pushed out to the liquid storage system shall be tapped off also from the main nitrogen supply.

3.10.4. Low pressure nitrogen shall also be used for purging/venting of samples boxes etc.

3.10.5. N2 shall also be tapped off to purge the polycarbonate sample boxes which shall be integrated in the reactor skids. For this purpose each line towards one reactor shall be equipped with a rotameter with needle valve to control the flow.

3.10.6. Nitrogen shall also be used as strip gas or carrier gas for the gas/liquid separators and stripping columns to remove the H2S from the liquid product.

3.11. <u>Tubing and Fittings</u>

3.11.1. For all tubings 316L stainless steel shall be used, the same can be confirmed during P&ID review.

3.11.2. The tubing shall be piped according to P&IDs.

3.11.3. Standard fittings as recommended by MRPL during design basis meeting or kick-off meeting for engineering phase shall be used.

3.12. <u>Reactor Specifications:</u>

3.12.1. MRPL shall be testing shaped extrudate catalyst in the units and the reactor should be capable of holding enough catalyst and inerts as specified in the objectives section above.

3.12.2. The preliminary reactor specifications mentioned are in this section and the final reactor dimensions cum specifications can be firmed up with MRPL during the engineering phase.

3.12.3. The reactor shall be dimensioned to allow for the optimization so as to minimize wall effects and maximize plug flow parameters (independent if up- or downflow is chosen).

Detailed calculations to ensure the said optimization parameters shall have to be made during the engineering phase in close collaboration with MRPL. The native files of calculations shall be shared with MRPL.

3.12.4. The catalyst bed shall be held in place by a filter frit in the VCR seal at the bottom of the reactor. Additional quartz wool shall be used to support the catalyst and as additional protection for downstream material entrainment.

3.12.5. Reactors shall have standard tubing with welded flanges at the top and bottom.

3.12.6. Gas and liquid shall enter the reactor at the top or bottom and the dip tube and thermocouples are inserted from the bottom.

3.12.7. For unit-1 the reactors shall be capable of parallel or series operation.

3.12.8. Reactors shall be conveniently removed from the rig by only cracking the VCR fittings at the top.

3.12.9. The mechanical design aspects shall be as below:

- Material of construction SS316L
- Design Temperature: 500°C
- Design Pressure: 300barg
- Welded Flanges at the top and bottom + VCRs
- Quartz wool and catalyst shall be supported by a SS
- Quartz wool and inert packing in inlet section shall be used for velocity and temperature profile development and proper distribution of liquid
- Shall include thermocouple dip-tube with multiple points for axial temperature profile
- Pressure tests shall be performed and demonstrated.
- Design calculations and material certificates shall be supplied

3.13. <u>Reactor Heating Modes:</u>

3.13.1. MRPL prefers to have the reactor heating to be of isothermal or adiabatic modes.

3.13.2. Isothermal heat mode means there is no temperature gradient on axial and along the whole length of the catalyst bed. Here the catalyst/reactor internal temperature needs to be controlled to achieve the same temperature over the whole length and breadth of the catalyst within ±1°C tolerance.

3.13.3. Adiabatic heat mode means the internal reactor temperature and reactor wall temperatures are balanced so that there is no temperature gradient or heat flux between the catalyst bed and the heating oven at each zone. In this case, there can be temperature gradient over the length of the catalyst depending on the type of reaction.

3.13.4. Zone wise split-shell ovens may be required to heat the reactors to achieve isothermal control and a minimum of 5-zone split-shell ovens are required for unit-1 while 3-zone split-shell ovens are required for unit-2.

3.13.5. Multi-port thermocouples shall be inserted in the reactor for measuring the axial profile with high accuracy and this shall also perform a master-slave control with the heater to directly control the internal catalyst temperature. MRPL expects unit-1 to have a minimum of 7 such ports and unit-2 to have minimum 3 such ports.

3.13.6. Every oven shall have a door-safety switch that cuts power in case the oven is opened.

3.13.7. The oven shall also contain two thermocouples per zone close to the heating wires - one for controlling each zone and other shall act as safety thermocouple.

3.13.8. The space reduction within the reactor due to insertion of multi-port thermocouples shall be accounted while optimizing for wall effects minimization and plug flow maximization so as to arrive at the reactors dimensions.

3.14. <u>Offline high-pressure sample possibility</u>

3.14.1. At the outlet of each reactor there shall be provision for taking a high pressure liquid offline sample by means of a sample vessel with shut-off valves and a pressure gauge for monitoring the inlet pressure.

3.14.2. The sample system shall be designed in such a way that by means of manual 3-way valves the oil outlet flow is routed through a custom sample. Liquid /gas enter from the bottom and leave at the top right. A small gas buffer shall remain at the top.

3.14.3. After switching back the 3-way valves to the normal outlet line the liquid shall be removed with valves at the bottom of the high-P sample system. A sample bottle is placed into a polycarbonate box, which shall be purged and the sample shall be withdrawn safely with protection from liquid spraying or H_2S gas removal

3.14.4. The sample box shall be enclosed with polycarbonate and there shall be a ventilation with nitrogen attached to the box that ensures continuous purging

3.14.5. The outlet tubing after each reactor shall be Ultrahigh-Purity (UHP) Stainless Steel Tubing.

3.14.6. The high pressure sample cylinder shall feature a PTFE coating. Both electro polished tubings and the PTFE coating shall be applied to limit sulfur H2S absorption on the metal surfaces.

3.15. Gas/liquid separations for Unit-1

3.15.1. There shall be two Gas/liquid separators for unit-1.

3.15.2. Both of them shall have pre-coolers capable of cooling upto 45°C.

3.15.3. Both of them shall have operating pressure flexibility varying from 190 barg to 25 barg.

3.15.4. Both of them shall be designed for flexible operating temperature between 450°C to 45°C

3.15.5. Both of them shall have 2-phase back-pressure controllers upstream and downstream with a turndown ratio of 1:10000

3.15.6. Vapor from both the separators have routing up options to recycle gas compressor RGC through gas cleaning section.

3.16. Gas/liquid separations for Unit-2

3.16.1. Unit-2 shall have a 2 phase back-pressure controllers, which shall replace conventional separators followed by H2S stripper configuration. A membrane-type backpressure valves capable of operating with 2-phase flows shall be employed for tight pressure control for the reaction.

3.16.2. 2 phase BPC shall have pre-coolers capable of cooling the direct reactor effluent whose temperature may vary from 500°C to 150°Cand the design shall take care of the same.

3.16.3. 2-phase back-pressure controllers shall have a turndown ratio of 1:10000

3.17. Automatic Pilot pressure Controller

3.17.1. The pressure control shall be achieved by directly piloting the 2 phase BPC valve with an electronic pressure control valve.

3.17.2. The controller shall precisely regulate the dome pressure with the hydrogen/nitrogen feed gas without being mounted directly in the process stream. This shall handle large pressure drops over the valve for convenient & smooth startup of the unit.

3.17.3. The electronic pressure regulator shall work in feedback control with another pressure transmitter mounted at the reactor inlet or outlet to directly control the reactor pressure.

3.17.4. There shall also be a reactor inlet pressure transmitter included and an automatic calculation of the differential pressure over the reactor shall be done by the software.

3.18. Integrated H_2 compressor for Unit-1:

3.18.1. MRPL prefers to have an integrated H2 compressor for Unit-1 as recycle gas compressor.

3.18.2. The compressor shall be compatible for recycle hydrogen with lighter hydrocarbons, H_2S, NH_3 etc. indicated in the feed section above.

3.18.3. The compressor shall have following features:

- Flow turn down: 500:1 minimum
- Suction pressure: 20 – 200 barg
- Discharge pressure: 25 - 500 barg
- Operating temperature: 45-150°C
- Leak-proof and odor tight
- All moving parts shall be continuously lubricated with oil.
- The compressor shall be dry-run safe and maintenance friendly. No sliding seals or packages shall be inserted in view of process safety.

3.19. Recycle gas cleaning column for unit-1

3.19.1. The recycle gas is required to be cleaned from H_2S in order to prevent its accumulation in the system. Provisions to by-pass this system shall be made so that operator at his choice may operate this system

3.19.2. The recycle gas shall enter the cleaning column and the gas shall come in contact with MDEA so that H_2S is being absorbed.

3.19.3. The column design shall be optimized for ensuring optimal residence times, gas velocities and proper MDEA contact and absorption of H_2S.

3.19.4. There shall be space for using structured or random packings in the column. Final packing type shall be agreed upon with MRPL at design basis stage. The flange or screw type connection at the top shall allow for opening and easy cleaning or changing of packings.

3.19.5. To ensure proper gas distribution in the amine phase and to provide enough gas/liquid interface bidder shall also include a distribution frit in the vessel.

3.19.6. Specifications of vessel shall be as listed here:

- Maximum pressure: 500barg
- Maximum temperature: 200°C
- Flange with bolts and nuts or screw type with O-ring at the top
- Shall be manufactured and constructed according to ASME Section VIII, Div.3.
- Bottom connection shall be with dished ends

3.20. <u>Stripping column</u>

3.20.1. The downstream stripper is required to ensure that olefin recombination does not occur and H_2S is fully removed from the liquid product, which shall result in false results otherwise.

3.20.2. The depressurized gas/liquid flow shall enter the stripper and gas and liquid separated, the product stabilized and H_2S perfectly separated from the liquid product.

3.20.3. The stripper design shall be optimized for ensuring optimal liquid residence times, gas velocities and proper N_2 addition and stripping of the liquid product.

3.20.4. There shall be space for using structured or random packings in the stripper. Final packing type shall be agreed upon with MRPL at design basis stage. The flange or screw type connection at the top shall allow for opening and easy cleaning or changing of packings.

3.20.5. Nitrogen strip gas shall enter the vessel from the bottom and leaving the separator at the top. To ensure proper gas distribution in the liquid and provide enough gas/liquid interface bidder shall also include a distribution frit in the vessel.

3.20.6. The strippers shall be another pressure controller mounted in the strip gas line after each stripper.

3.20.7. Specifications of stripper shall be as listed here:

- Maximum pressure: 10barg
- Normal operation pressure: 1-10barg, depending on feeds etc.
- Maximum temperature: 200°C
- Flange with bolts and nuts or screw type with O-ring at the top
- Shall be manufactured and constructed according to ASME Section VIII, Div.3.
- Bottom connection shall be with dished ends

3.20.8. The stripper or gas/liquid separator shall have heating provision with a heating jacket for both the liquid level and the larger gas section above.

3.21. Liquid Level Measurement and Control

3.21.1. The liquid level in the separator/stripper shall be measured by delta pressure transmitter.

3.21.2. The level transmitter shall work together with a compact size needle type control valves at the liquid outlet line at the bottom of the separator vessel for a continuous level control.

3.21.3. Bidder shall include an additional shut-off valve after the control valves to avoid vapor blow-by to liquid removal line.

3.21.4. The specifications of the compact size needle type valves shall be as below:

- 1/4" Control valve type RC 200
- Globe casted, material 316 SST
- Connection: 1/4" NPT
- Bonnet: Standard, material 316 SST
- Stem seal: PTFE/PFA
- Inner valve: Size "P1" linear; Kvs 0,0017; plug and seat 316 SST (sized for 3-15 barg inlet, 1 bar outlet, 0.1 – 1.5 ml/min liquid flow)
- Actuator: pneumatic type, fail close, type 754, ATO signal 0.4 – 1.2 barg
- Mounting lubricant: Silicone containing Dow 111

3.22. Product Fractionator column for Unit-1

3.22.1. Downstream of H_2S stripper, product fractionator is required to split the liquid fractions into minimum 3 cuts namely naphtha boiling upto 150°C, distillate boiling upto 370°C and unconverted oil which boils above 370°C. All the temperatures indicated are TBP end points.

3.22.2. Operators shall have the option to increase the reboiling up to 380°C and change the naphtha & distillate cut points up to ±20°C.

3.22.3. The fractionator design shall be optimized for ensuring optimal liquid residence times, gas velocities, N_2 addition for stripping if necessary.

3.22.4. There shall be space for using structured or random packings in the fractionator. Final packing type shall be agreed upon with MRPL at design basis stage. The flange or screw type connection at the top shall allow for opening and easy cleaning or changing of packings.

3.22.5. Specifications of fractionator shall be as listed here:

- Maximum pressure: 10 barg
- Normal operation pressure: 1-10 barg, depending on feeds etc.
- Maximum reboiling temperature: 380°C
- Shall be manufactured and constructed according to ASME Section VIII, Div.3.
- Bottom connection shall be with dished ends

3.23. Automatic liquid sampling

3.23.1. Automatic liquid sample system with minimum 4 samples shall be included in the system.

3.23.2. Bidder shall employ an effective liquid sampling that includes a series of 3-way valve in series. The last valve shall lead to heated slop vessel. This approach shall be configured to ensure all 3-way valves are continuously purged by liquid and only when a sampling vial is to be filled does a 3-way valve switch. This approach shall be made to ensure nearly dead-volume-free and that all valves and tubing are continuously purged.

3.23.3. The valves shall be set up to vent to a common header via a tube-in-tube connection led to the vent so that now degassed gases are emitted into the ITEM enclosure.

3.23.4. Liquid sample bottles shall be placed behind a polycarbonate protection. Cooling water provision to add by a thermostat to a tray/sample block if the sample has to be stabilized or the product vessel can be cooled shall also be provided.

3.24. Oil Product vessels and product balances

3.24.1. The product vessel shall be the same type of vessels as the feed vessels as mentioned in clause 3.5 above

3.24.2. Nitrogen shall be employed in the vessels to push out the liquid product with overpressure via the bottom connection towards another storage vessel or drain system of MRPL and bidder shall design the system accordingly.

3.24.3. The oil feed vessel is weighed on a 35kg balance + 5kg overload and 0.1g accuracy for unit-1 and 5kg balance + 0.5kg overload and 0.01g accuracy for unit-2.

3.25. Automatic GC sampling

3.25.1. There shall be provision for taking automated GC samples after the gas-liquid separator/stripper for making a tail gas analysis of the C1-C5 and C6+ gaseous outlet products from each reactor possible

3.25.2. Bidder shall install a closed loop sampling system. The pressure regulator shall give enough driving pressure for sampling. The GC outlet shall be connected back to the outlet line of each reactor before the Wet Gas meter

3.25.3. Small internal diameters shall be used for the sample lines to have low residence times and fast flush times of the sample lines.

3.25.4. The GC shall also be triggered by the bidder's software and all GC data can be integrated into the consolidated report of all process data of the unit so as to minimize post processing work to combine both the GC and unit reports.

3.26. Online Multi-Channel Analyser

3.26.1. A multi-channel analyzer based on GC shall be equipped with one Thermal Conductivity Detectors (TCD's), 2x Flame Ionization Detector (FID) and a custom valve box. This valve box option shall accommodate the sampling- and column switching valves as well as the micro-packed columns.

3.26.2. Each channel shall be fully independent and designed to determine the concentration of all permanent gases, including hydrogen, hydrogen sulfide and the individual saturated and unsaturated hydrocarbon components up to and including C5 (C6 and higher components as a composite peak) and in a single analysis. The parallel set-up of the channels shall allow MRPL to run these channels simultaneously resulting in a short analysis time of less than 5 minutes (including H_2S).

3.26.3. Bidder shall completely integrate the multi-channel analyzer within the system including the supply of all carrier gases / hydrogen for the FID, purification columns, and pressure reducing regulators.

3.26.4. The multi-channel analyzer shall be equipped with 1x TCD and 2x FIDs for the detection of permanent gases on the TCD and hydrocarbons from C1-C5 on the1st FID and hydrocarbons from C6-C20 on the 2d FID.

3.27. Volumetric Gas Flow Measurement

3.27.1. The gas flow leaving the separators/strippers of each reactor-set shall be sent to a wet gas meter which shall measure the total volumetric flow. The signal shall measure by a pulse counter (200 impulses per gas-meter rotation).

3.27.2. Bidder shall install a separate overpressure-relief protection with a water filled burette that opens at 100mbar, preventing possible overpressure from occurring in the wet-gas meter.

3.27.3. The wet gas meters shall have an SS casing and design pressure of 500mbar.

3.27.4. Separate pressure transmitters and thermocouples shall be present for measuring pressure and temperature at the wet gas meter to convert to Nl/hr accurately.

3.28. <u>Note on Mass Balance</u>

3.28.1. Mass balance shall be performed based on a feed and product chemical analysis. Mass balances of C, H, S and N shall also be performed.

3.28.2. Following instruments shall be employed:

- Mass flow and total amount of liquid feed (weighing scales / flow meter)
- Hydrogen or other gaseous feed flow-rate and total amount (mass-flow-controllers with totalizer)
- Stripping gas flow-rate and total amount (mass-flow-controllers with totalizer)
- Wet gas flow meter placed on the gas outlet line from the separator to quantify a total mass of gas products (hydrogen + stripping gas + light gases C1-C5)
- Online multi-channel analyzer for C1-C6+ (capture any entrained liquids)
- Weight balance to weight the amount of product liquid feed
- Liquid samples for S, N etc. analysis + SimDis

3.29. <u>Knock out vessel</u>

3.29.1. The vents of PSV, RD or pressurized equipment shall be conducted to vent through knock-out vessels

3.29.2. The knock out vessel shall have sufficient volume for vapor-liquid disengagement.

3.29.3. Relief valves / rupture discs shall be before bundled properly in a large tube and sent via heated lines to a slighty heated knock-out pot.

3.29.4. Detailed design and calculation of the relief section shall be done during detail engineering phase as per API 520 and other relevant codes.

3.29.5. Small cold knock-out pots shall be used for the main gas outlets to capture any entrained liquids if any.

3.30. Note on heat tracing and insulation

3.30.1. Bidder shall employ heat tracing of all process lines around the liquid feed lines, and gas/liquid outlet lines after the reactor including the strippers and liquid sample lines as requested by MRPL during P&ID review. This shall be realized by multiple heat traces / custom heat matts wrapped around tubes and components.

3.30.2. Bidder shall use custom heating jackets with quick-fit connections to heat various parts uniformly when applicable for easy maintenance. Flexible heat jackets with quick-fit connections shall allow fast open/closing of the reactors and reduce the downtime of the unit.

3.30.3. Since the heat consumption is different for various parts of the unit bidder shall use multiple heat traces/heat jackets. This shall be extremely important to realize uniform heat tracing and prevent cold spots in this unit. Each heat trace shall be equipped with two thermocouples (one for controlling, one for safety purposes) and shall be placed in separate I/O cards.

3.30.4. Bidder shall ensure great care to use thick insulation and provide sufficient space in the piping and unit to make it possible to still access all components within the setup.

3.30.5. Bidder shall ensure that all mounted components are thermally insulated from the mounting supports on which they are placed.

3.31. Profile Design and Layout

3.31.1. The entire unit shall be mounted in a closed and ventilated ITEM Aluminum profile

3.31.2. The entire system shall be capable of passage fully or in part, if reassembled at MRPL site, within MRPL R&D's pilot reactor house door height of **6 ft and width of 3 ft.**

3.31.3. Indicative layout shall be suggested by bidder and the total system's layout shall fit inside a maximum footprint of 200 ft^2. Maximum reassembled system height shall be limited to 8 ft.

3.31.4. The design shall be such that access for the feed section is from the back and access to the reactors and product section is from the front. Objective is to provide better access to parts for operation and maintenance.

3.32. Process Control System

3.32.1. OPEN-Software Philosophy: Bidder shall offer an open software structure based on industry-standard systems. MRPL shall have complete ability to change or maintain the software if desired.

3.32.2. The automation of this unit shall be mainly performed by a dedicated control system and its auxiliaries which shall be mounted in one cabinet.

3.32.3. The final alarm interlock matrix defining the necessary responses for various alarms shall be decided in close collaboration with the MRPL during P&ID review.

3.32.4. Vendor shall use separate relays for BPCS and safety alarming /relieving or other such interlocks. Safety system shall have only relays and foundation field bus or similar system shall not be employed for safety instrumentation.

3.32.5. The control system shall be manually operated at the operator station which runs on PC.

3.32.6. Bidder shall supply a Workflow Manager application designed for unit operators and it shall provide seamless integration of all of experimental steps and acts as the link between analytical devices and bidder's testing units. It shall be flexible to configure experimental workflows as well as implementation of powerful data-logging tools so to enable the user to execute complex, multistep experiments with the click of a mouse.

3.32.7. Experiment-to-Experiment and operator-to-operator reproducibility shall be ensured by virtue of full-automation through the workflow managers.

3.32.8. Additionally, the workflow managers program shall enable operators to share, modify and execute workflows. It shall also enable operators to use loops, cases, parallel running parts and can also combine steps into sub-sequences and use this sub-sequences as a new kind of step etc. including parallel execution of independent workflows.

3.32.9. Graphical User Interface (GUI): For the operation of this system unit vendor shall create and supply a number of pre-defined user interfaces. These screens shall be designed to ensure that users/operators have fast and simple access to all relevant process parameters, alarm annunciation and adjustments, recipe system and all relevant other options for safe and easy operations.

3.32.10. Alarming: In order to maximize safety, temperature alarms shall be handled completely separately from the temperature control loop. Two separate sensors shall be used (one for alarming, one for control) and separate hardware shall be used to acquire the signals.

3.32.11. PC shall display detailed information on the current situation to the operator. A contact shall be made available for external alarm circuits should the user wish to trigger an external event based on an alarm in the unit. The alarms and the actions which they initiate shall be fixed in the alarm interlock matrix.

3.32.12. Historical Data: Vendor's process control system shall provide a robust trending functionality for the historical data and trending of all I/O. The historical trend GUI shall enable the user to export data chosen by the user for analysis or visualization in MS Excel.

3.32.13. The software shall store historical data and allow the user to review all important process data in historical charts. Alarms and events shall also be logged to the hard disk.

3.32.14. Reporting: Data shall be logged to a reporting tool and shall allow to log all tags in the OPC servers available.

3.32.15. Password Security: In order to avoid interference from not authorized personnel, vendor shall implement a password system with three access levels. The various levels and their related functionalities are listed below.

- Operator
  - Operation of the unit
  - start/stop recipes
- Engineer
  - change alarm settings
  - create and adapt recipes
  - change parameters
- Administrator
  - all rights

3.32.16. Access and actions by users shall be logged automatically with user name.

3.32.17. Hardware and Cabinet(s): Bidder shall supply the electrical hardware, required to control the reactor unit. The hardware shall be installed in a control panel.

3.32.18. The cabinet shall be provided with status lamps, an alarm reset button and an ESD button. On top of the cabinet, a status pile shall be mounted with three colors providing immediate indication to the user of the status of the unit.

3.32.19. Screw terminals and system connections shall be provided in the cabinet to allow connections from the cabinet to the plant equipment. Power to the external plant equipment shall be supplied via the control panel, the cabinet and the auxiliary equipment are switched with one main switch.

3.32.20. Wiring in the control panel shall be supplied and tested, the wires in the cabinet shall be provided with standard wire identification labels based at connection number.

3.32.21. Depending on the size of the system vendor shall recommend to integrate the cabinet into the system or build it separately.

3.32.22. I/O Types: The unit is connected to the cabinet with analogue and digital I/O modules.

3.32.23. When more complicated instruments or instruments with a high resolution are used we implement network based connections as these provide significantly better resolution.

3.32.24. Cabling: In order to reduce the amount of cabling a part of the IO shall be installed in the unit. For others, 24 Vdc cables and 230 Vac cables multi core cables shall be used.

3.33. Safety Devices and Concept

3.33.1. MRPL's R&D is located within factory boundary limits and is therefore governed by factory act along with relevant industrial safety norms. Vendor shall be familiar with all relevant industrial safety norms and the supplied item & services shall be incompliance with the same.

3.33.2. Vendor shall carry out a HAZOP, SIL and risk analysis according to ISO 13489 for this system internally and subsequently jointly with MRPL at appropriate project schedule.

3.33.3. Functional safety items shall be SIL classified according to VDE/VDI 2180. SIL 1 items for the gas detectors and the ventilation switch are required.

3.33.4. All loops except gas detectors & ventilation switch shall be minimum SIL-2 complaint and high pressure reactor loop shall be of SIL-3 complaint.

3.33.5. Vendor shall perform a ventilation calculation of the unit to determine required suction capacity based on expected leak rates and worst case scenarios.

3.33.6. Over-temperature: All over-temperature alarms shall be controlled by separate over-temperature safety switches. Separate thermocouples shall be used for BPCS and safety interlock or alarm purpose.

3.33.7. Overpressure: Overpressure protection shall be provided by overpressure relief valves for the feed gas lines and feed & product tanks. The reactors are directly secured by certified bursting/rupture discs. Pressure vessels relieving are to be calculated according to API 521 codes.

3.33.8. Ventilation / Flow monitoring: Ventilation shall be monitored by a ventilation sensor with LL alarm and local display. It shall be installed in the ventilation duct onsite at the MRPL.

3.33.9. A safe unit shut-down shall be done in case the ventilation of the unit fails.

3.33.10. Changes to the design resulting from the safety meetings, SIL and area classification shall be carried out by the vendor during P&ID, HAZOP & SIL study jointly with MRPL.

3.33.11. Detectors: A digital input and a digital output signal shall be present so that the unit can communicate with the local safety infrastructure at the MRPL laboratories.

3.34. Preferred Manufacturer

The following preferred manufacturers of MRPL shall be used for this project:

3.34.1. Pressure transmitters: Siemens, BD sensors, WIKA

3.34.2. Pressure Gauge: Swagelok or Wika

3.34.3. Control valves: Equilibar, Badger

3.34.4. Pressure reducing valves: TESCOM or Gasarc/HPS

3.34.5. PSV and rupture disk: Schlesinger, Leser, Lorch

3.34.6. Temperature transmitter: Thermocouple type K for reactor, Thermocouple type N, Thermosensor, TMH

3.34.7. Weight Scale: Sartorius (Supreme Balance)

3.34.8. Mass Flow Controller (Gases): Bronkhorst, Brooks

3.34.9. Wet Gas Flow meter : Ritter

3.34.10. Flow transmitter (Liquid): Bronkhorst, Siemens, Endress Hausser, Emerson

3.34.11. Hand valves, piping, thread and accessories: Swagelok

3.34.12. Temperature Switch: TSS: PR electronics or JUMO

3.34.13. Solenoid valve: FESTO module.

3.35. Specific Requirements of MRPL

3.35.1. Valves and components shall be chosen without elastomer seals

3.35.2. Wherever elastomer seals shall be employed please follow:

- KALREZ seals for service in contact with H_2S and/or liquid feeds

- Other location seals without H_2S in liquid or gas contact shall (N_2, air etc) be either of Teflon or EPDM type

3.35.3. For high pressure and temperature lines, Swagelok 1R series needle and shut-off valves to be employed.

3.35.4. Bronkhorst's El-flow F-221M high-P/delta P thermal mass-flow-controllers which uses a vulcanized valve plunger to be employed for H2 mass flow control.

3.35.5. Liquids to have two type of mass flow meter installed:

- High temperature Coriolis flow meters from Siemens SITRANS Mass 2100 DI 1.5 for high flow and high temperature feeds
- Bronkhorst mini Coriolis MFCs for low-flow applications and cold liquid feeds

3.35.6. Liquid feeds shall be pumped with LEWA FC 1 series hydraulically actuated diaphragm metering pumps. HPLC pumps shall not to be installed

3.35.7. Integrated H2 Compressor: Air piston type compressor from Haskel shall be used for integrated recycle gas compressor service.

3.35.8. MRPL will be testing commercial extruded catalysts as well as catalyst particles size of 1mm to 4mm. Reactors sizing to be carried out to minimize wall effects and axial mixing. Sizing calculations shall be shared with MRPL to comply with and confirm the same.

4. Scope of Work

The following shall only be the items, infrastructure and facilities from MRPL for MMPU and all the other requisites in terms of hardware, software, utilities, consumables, chemicals and services shall be in the scope of the vendor:

4.1. Housing the item in a covered building of around 200 sq. ft. area at ambient conditions (without any HVAC). The maximum permissible height of the system shall be 8ft.

4.2. Manpower for MMPU operation upon suitable and appropriate training services by the vendor

4.3. Feedstocks (Liquid & Gases) and catalysts for testing and evaluation

4.4. Utilities such as N2/IA/PA, steam, cooling water, DM water and power. The utility conditions shall be defined during design basis meeting and for cost estimation purpose vendor can assume typical industry standard conditions.

4.5. Sufficient lighting

Anything other than those mentioned explicitly above required for successful design, fabrication, construction, transport, assembling at MRPL site, calibration, testing, commissioning, training, maintenance, safety, compliance with statute or norms, inspection, electrical, instrumentation and control or in any aspect of this system delivery, SAT, successful sustained operation of MMPU etc. as defined in this document or otherwise shall be in the scope of vendor and the vendor's commercial offer may account for the same.

5. Project Workflow

5.1. Kickoff meeting - design review (at MRPL)

5.2. Safety Analysis at Bidder or MRPL site (HAZOP etc. with MRPL)

5.3. Pre-Engineering phase

5.4. Approval of Engineering Documents by MRPL

5.5. Purchase of components

5.6. Review and approval of electrical drawings by MRPL

5.7. Review and approval of layout 3D drawings by MRPL

5.8. Manufacturing of the system by Vendor

5.9. Progress visits by MRPL (2 are envisaged)

5.10. Internal testing and commissioning of unit

5.11. FAT: Checking the basic functional capability together with MRPL at Vendor's location (including viscous inert feeds + nitrogen/hydrogen)

5.12. Delivery of the system to MRPL

5.13. Installation of the system by bidder onsite

5.14. Commissioning and Operator Training by bidder onsite.

5.15. SAT: Site Acceptance Test of the system at the customer (with real feeds and hydrogen)

6. Approval of Engineering Documents

6.1. The following documents as a minimum shall be reviewed and approved by MRPL:

6.1.1. PFD

6.1.2. P&ID

6.1.3. P&ID Parts List

6.1.4. Interlocks – Cause & Effect Alarm Matrix

6.1.5. Datasheet of all equipments

6.1.6. Hazard Analysis

6.1.7. Native files of calculations for optimization, safety relieving etc. as mentioned above

6.2. These documents have to be approved by MRPL in written form before manufacturing or fabricating the system and in this context, the final revision incorporating MRPL's comment shall be compiled and supplied as Final Engineering Design Package to MRPL as per the schedule.

7. FAT (Factory Acceptance Test)

7.1. The basic functional capability of the system shall be checked during a 5-day FAT.

7.2. This FAT shall be carried out together with the MRPL's presence at vendor's premises;

7.3. Within the FAT, the following tests shall mainly be carried out:

7.3.1. Line checks

7.3.2. Visual checks

7.3.3. Operating the reactors

7.3.4. Pressure Testing and pressure control

7.3.5. Full Functionality testing including e.g.

- Flowing inert gas flows
- Dosing inert liquid
- Heating/cooling, vaporizing or Sampling
- Gas and liquid sampling tests

7.4. After these tests, a test-document (FAT-Protocol) shall be prepared and signed by both MRPL and vendor. A signed FAT document shall be expedited before shipping the system.

8. Final Engineering Design Package

Documentation, all in English language only, in the form of Final Engineering Design Package shall be supplied which shall include final revision incorporating MRPL's comments, but is not limited to the following:

8.1. PFDs

8.2. P&IDs and Cause & Effect Matrix

8.3. Mechanical drawings

8.4. Instrumentation drawing

8.5. Electrical drawings

8.6. Start up, Shutdown and Emergency Protocols

8.7. User manuals for system and process control system in English

8.8. Standard Operating Procedure

8.9. Procedure for instrument or equipment calibration, maintenance and installation

8.10. Datasheets and user manuals of relevant 3rd party components in English

8.11. Minutes of meetings of all review discussions like P&ID, SIL, HAZOP etc

8.12. PSV or rupture discs design or calculations

8.13. Certificates required as per relevant regulations

All the above documents shall be in pdf along with editable native files like MS-Word, MS-Excel, AutoCAD etc.

9. Delivery Time & Conditions

9.1. Finalization of Design Basis - 0 week

9.2. Process Flow Diagrams - 2 weeks

9.3. Piping and Instrumentation Diagrams (P&IDs) - 4 weeks

9.4. P&ID, HAZOP & SIL review - 6 weeks

9.5. Datasheet & calculations - 10 weeks

9.6. Final Engineering Design Package - 20 weeks

9.7. Layout 3D model review -24 weeks

9.8. FAT - 34 weeks

9.9. Classroom training upto 15 MRPL personnel - 41 weeks

9.10. Whole System Delivery at MRPL site - 42 weeks

9.11. Notice of Readiness (NoR) for SAT at MRPL site - 44 weeks

9.12. SAT at MRPL - 46 weeks

9.13. Operator training upto 8 MRPL personnel - within 2 weeks after SAT

9.14. Vendor shall mobilize vendor's personnel for reassembling the item if necessary at MRPL site and NoR for SAT shall be tendered within 2 weeks from the items date of arrival at MRPL's R&D location.

9.15. MRPL shall arrange chemicals, feed etc. for SAT within 2 weeks from the date of tendering of NoR for SAT by the vendor.

9.16. For any delay in the aforesaid schedule, MRPL shall detect 0.5% of the purchase order value per calendar week delay upto to a maximum of 10% of the order value.

10. Commissioning and Operator Training

10.1. Within the commercial quote, vendor shall include all aspects mentioned in the scope & deliverables including re-setup, transport, commissioning and training at the MRPL`s site.

11. SAT / Qualitative Acceptance

11.1. SAT tests shall be performed as per the mutually agreed protocol between bidder and MRPL during HAZOP & SIL Study stage.

11.2. If the MMPU system fails in terms of hydraulics or any other hardware performance during SAT, vendor shall rectify the same within at his own expense and at no charge to MRPL.

11.3. Such rectification shall be completed and vendor shall demonstrate the successful performance of MMPU within 4 weeks of 1st SAT attempt.

11.4. If the MMPU system doesn't perform even after the first attempt of rectification of faulty parts during 1st SAT attempt or within 4 weeks of unsuccessful first attempt of SAT whichever is earlier, MRPL shall detect 20% of the purchase order value as an exclusive remedy for the same.

12. Payment Terms

12.1. 10% upon Project Kick-off meeting completion

12.2. 10% after design basis sign-off

12.3. 20% after Final Engineering Design Package delivery

12.4. 20% after FAT completion report sign-off

12.5. 30% after Whole System delivery at MRPL site

12.6. 10% after SAT, completion of operator training and successful delivery of all deliverables.

12.7. Cost of travel and living expenses for this project towards any location shall be borne by MRPL for MRPL's personnel and vendor for vendor's personnel.

13. Warranty

13.1. Warranty for 24 months after SAT shall be provided by the vendor.

13.2. Vendor shall service /supply the faulty hardware, software, spare or any component required for sustainable & successful operation of MMPU without any charge under this period.

14. Annual Maintenance Contract (AMC)

14.1. MRPL at its option may use the services of vendor and commercial offer shall include optional cost of AMC for 5 years from warranty period. Details of AMC service shall also be indicated in the offer.

14.2. If the AMC service cost varies year wise or has an escalation factor, the same shall be indicated.

15. Details Expected from the Bidder

The following details/information are sought from the prospective bidders in the form of proposal or offer:

15.1. Cost for unit -1 100ml reactor setup.

15.2. Cost for unit-1 500ml reactor setup.

15.3. Cost for unit-1 950 ml reactor setup.

15.4. Cost for unit-2 10 ml reactor setup.

15.5. Footprint area of all the aforesaid reactors individually.

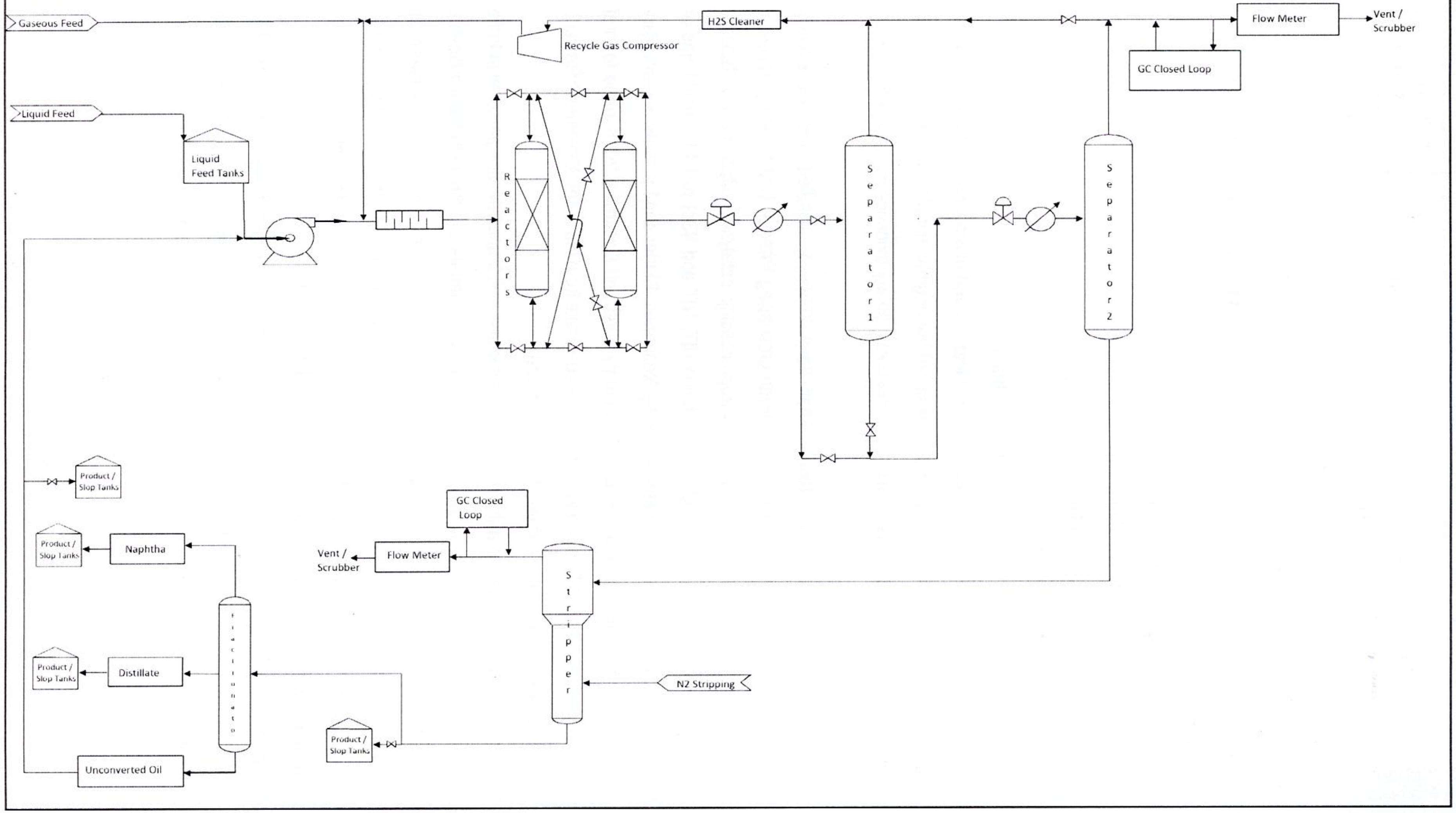
15.6. Nature of the bidder as whether an original manufacturer (OM) of proposed Multipurpose Multi-reactor Pilot Unit (MMPU) or an authorized dealer of the original manufacturer. If the bidder is an authorized dealer of OM, they shall submit the documentary evidence such as authorization letter from the OM.

15.7. Prior experience of the bidder: Bidder shall have supplied, installed and successfully commissioned at least one number of Pilot Hydroprocessing Reactor Unit for the purpose of R&D or testing and evaluation of typical hydroprocessing catalyst portfolio to any Refinery Quality Control Laboratory or Academic Institution (IIT, NIT and IISc) or CSIR-Institutions or Government and other R&D Centers set up by Refineries. Bidder shall provide documentary evidence for the same carried out between January 2008 and December 2018 in the form of Purchase order copy, SAT copy and performance certificate from the client. Minimum three such documents with order value details shall be provided.

15.8. The bidder shall have well established service center and well trained service personal in India for the MMPU indicated. The bidder shall offer service/maintenance of the instrument indicated in the tender at MRPL site only OR at the bidder's service center located in India. Bidder shall submit proof of the said criteria in the form of documentary evidence for carrying out such service for a reputed Indian Client between January 2008 and December 2018. Minimum one such document with order value and service details shall be provided.

15.9. The bidder shall agree to enter into AMC/CMC after the warranty period. Optional cost of AMC for 5 years from warranty period shall be provided with unit-wise break up for the reactor capacities mentioned above. Details of AMC service shall also be indicated in the offer.

MMPU -1


Gaseous Feed
Liquid Feed
Liquid Feed Tanks
Recycle Gas Compressor
H2S Cleaner
Flow Meter
Vent / Scrubber
GC Closed Loop
Reactors
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Separator 2
GC Closed Loop
Flow Meter
Vent / Scrubber
Stripper
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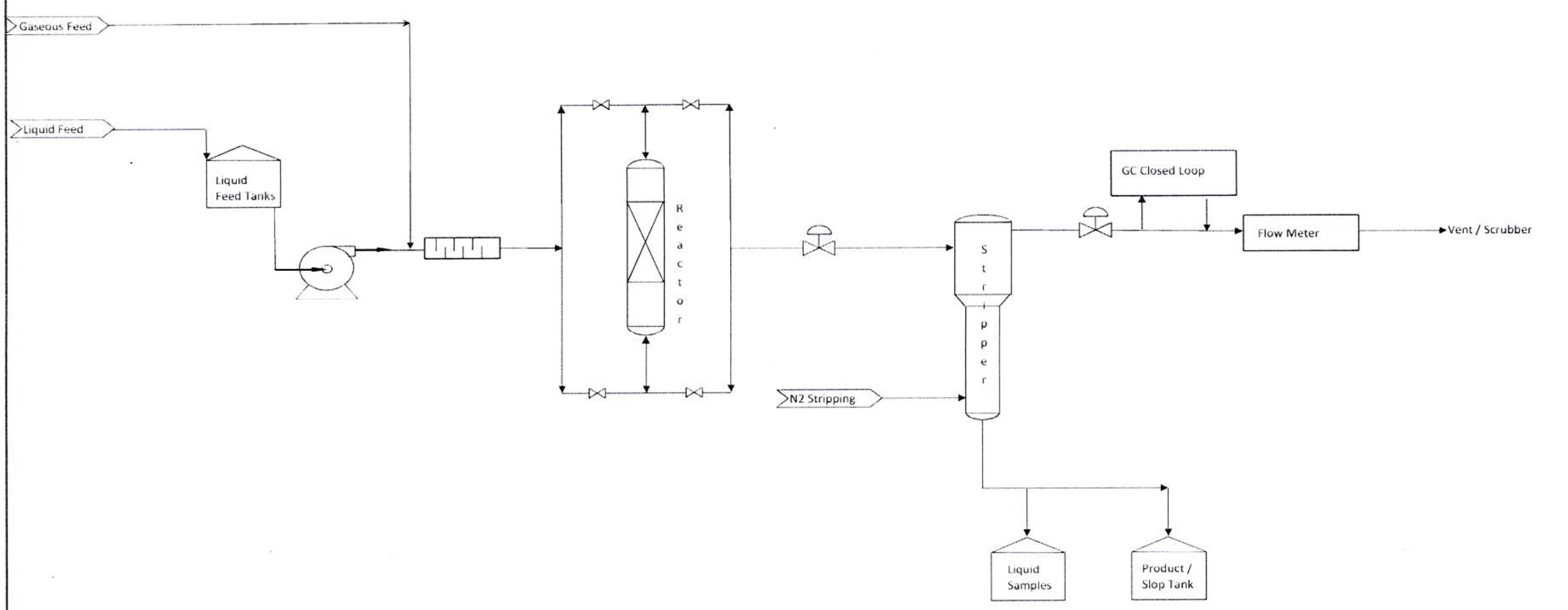
Product / Slop Tanks

MMPU -2



Gaseous Feed
Liquid Feed
Liquid
Feed Tanks
Reactor
N2 Stripping
Stripper
GC Closed Loop
Flow Meter
Vent / Scrubber
Liquid
Samples
Product /
Slop Tank