

2. Process Description

This process is composed of the following nine sections;

- 1) Isobutylene Oxidation Section
- 2) Waste Gas Catalytic Incineration Section
- 3) HB Separation and MAA Recovery Section
- 4) MACR Recovery Section
- 5) MAA Extraction Section
- 6) Esterification Section
- 7) Purification Section
- 8) Incineration Section
- 9) Combustion with Submerged gas Quench Section

Abbreviation:

IB	: Isobutylene
MACR	: Methacrolein
MAA	: Methacrylic Acid
MMA	: Methyl Methacrylate
ME	: Methanol
HB	: High Boiling impurities in products gas

IB is oxidized in vapor phase catalytic reactions to MAA through MACR in **the Oxidation Section**.

The Waste Gas Catalytic Incineration Section is provided to treat the waste gas from the MACR recovery section. A part of the combustion gas from the waste gas catalytic incineration section is utilized as diluents for the reactant gas.

The product gas is introduced to **the HB Separation and MAA Recovery Section**, where almost all of HB is condensed and that condensed liquid is filtered to separate the undissolved solid. That filtered solid is dissolved with caustic soda then fed to the combustion with submerged gas quench section. MAA, acetic acid, acrylic acid and water are recovered to the MACR recovery section via vaporizers. The vaporizing residue is burned in the Incineration section.

Unreacted MACR is recovered through absorption and stripping **in the MACR recovery section**. The recovered MACR is recycled to the oxidation section. The tail gas is sent to the waste gas catalytic incineration section.

MAA aqueous solution is fed to **the MAA Extraction Section**, where MAA is extracted from the solution by a solvent and separated from the extract by distillation.

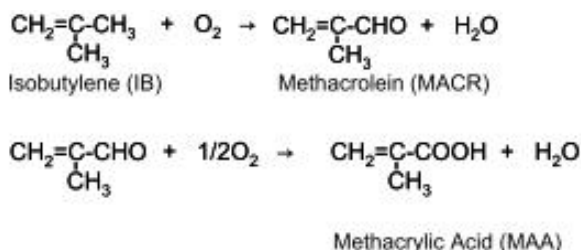
The obtained MAA is esterified with ME to MMA in **the Esterification Section**.

MMA is further purified through light-ends cut and heavy-ends cut in the Purification Section.

Waste water and waste oil from above seven sections are safely burned in **the Incineration Section and the Combustion with Submerged gas Quench Section** except waste water from esterification. This waste water is treated by Biological Treatment Plant in OSBL.

2.1 Isobutylene Oxidation Section

IB is oxidized to MAA by the following two stage reaction :



IB is oxidized to MACR in the first oxidation reactor (R-1010) and MACR is almost oxidized to MAA in the second oxidation reactors (R-1020A/B).

Major by-products are generated by the following reaction.

1. Carbon mono-oxide (CO) : $\text{C}_4\text{H}_8 + 4\text{O}_2 \rightarrow 4\text{CO} + 4\text{H}_2\text{O}$
2. Carbon di-oxide (CO₂) : $\text{C}_4\text{H}_8 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}$
3. Acetaldehyde (ACH) : $\text{C}_4\text{H}_8 + \text{O}_2 \rightarrow 2\text{CH}_3\text{CHO}$
4. Acetone (ACT) : $\text{C}_4\text{H}_8 + 2/3\text{O}_2 \rightarrow 4/3(\text{CH}_3)_2\text{C}=\text{O}$
5. Acetic acid (ACD) : $\text{C}_4\text{H}_8 + 2\text{O}_2 \rightarrow 2\text{CH}_3\text{COOH}$
6. Acrolein (ACR) : $\text{C}_4\text{H}_8 + 4/3\text{O}_2 \rightarrow 4/3\text{CH}_2=\text{CH}-\text{CHO} + 4/3\text{H}_2\text{O}$
7. Acrylic acid (AA) : $\text{C}_4\text{H}_8 + 2\text{O}_2 \rightarrow 4/3\text{CH}_2=\text{CH}-\text{COOH} + 4/3\text{H}_2\text{O}$
8. Maleic acid : $\text{C}_4\text{H}_8 + 3\text{O}_2 \rightarrow \text{C}_4\text{H}_4\text{O}_4 + 4\text{H}_2\text{O}$

1) First Oxidation Reactor (R-1010)

IB is introduced from other Unit. Then, it is treated by IB (C4) dehydrator (Z-1045) to remove saturated water in IB after it is cooled down by Brine with Isobutylene cooler and heat recovery (E-1045A/B).

IB, vaporized at a pressure of 2 kgf/cm²ga in the Isobutylene vaporizer (E-1040) and superheated in the heater (E-1042), is introduced into the first oxidation reactor (R-1010) feed mixer (M-1010) at a given flow rate through the isobutylene gas holder (D-1042).

The reactant feed gas is prepared by mixing fresh air from the air blower (B-1010), inert gas from the waste gas incineration system through recycle gas blower (B-1020), steam and IB gas at respectively given flow rate to assure the safety and optimum operation sufficiently outside the inflammable limit.

And additional Nitrogen gas is introducing reactor with reactant to avoid inflammable limit during start up state and no nitrogen is required on normal operation except small amount of nitrogen as seal and unplugging gas.

The reactant temperature is preheated by the first air pre-heater (E-1015) due to preventing low reacted gas temperate at inlet of catalyst.

The reactant feed gas is led to the bottom of R-1010.

This reactor is made of fixed bed multi tubular shell and tube type reactor having an intermediate tube sheet to separate the reaction section and the quenching section. The first stage oxidation catalyst is filled in the tubes up to the height of intermediate tube sheet and heat transfer salt (HTS) is circulated as a coolant through the shell side.

In the reaction section below the intermediate tube sheet, almost all of the isobutylene fed is oxidized to MACR accompanying a small amount of by-products. Some of the MACR produced is consecutively oxidized to MAA.

The reaction temperature (controlled HTS temperature) is from 335 to 380 deg. C.

To make the uniform reaction temperature, a large quantity of HTS is circulated through the shell side by the HTS circulation pump (P-1010A/B).

The reaction temperature is adjusted so as to keep the reaction optimum, by checking the conversion of IB and the selectivity to MACR and MAA at the reactor outlet.

Above the intermediate tube sheet is the quenching section, where the reaction product gas is quenched to around 285 deg.C for suppressing the auto-oxidation of MACR.

The reactor tubes at the quenching section are filled with packing, and the quenching temperature is kept uniform by circulation of HTS that driven by HTS circulation pump (P-1010C).

For the control of reaction temperature, the circulating HTS is cooled at HTS waste heat boiler (E-1051A) through temperature control valve, generating steam of 40 kgf/cm²ga. The cooled HTS is come back to the upper and lower sections of the reactor shell. For the control of quench temperature, the circulating HTS is cooled at another HTS waste heat boiler (E-1051C) through temperature control valve.

2) Second Oxidation Reactors (R-1020A/B)

The reaction product gas from R-1010 is mixed with the recovered MACR gas from the MACR stripping column (T-1130) and fresh air from B-1010. The recovered MACR gas is pre-heated by the T-1130 top gas pre-heater (E-1132) and the second air is pre-heated by pre-heater (E-1025).

These gases are mixed by the second oxidation reactors (R-1020A/B) feed mixer (M-1020) and led to the top of R-1020A/B. About 65 to 75% of introduced MACR to these reactors is oxidized to MAA through the second stage catalyst packed in the reactor tubes.

The reactors are also fixed bed multi tubular shell and tube type, and the reaction temperature control system is same as R-1010.

The reaction temperature is from 280 to 320 deg.C.

To make the uniform reaction temperature, a large quantity of HTS is circulated through the shell side by the HTS circulation pump (P-1020A/B).

The reaction temperature is adjusted so as to keep the reaction optimum, by checking the conversion of MACR and the selectivity to MAA at the reactor outlet.

For the control of reaction temperature, the circulating HTS is cooled at HTS waste heat boiler (E-1061A/B) through temperature control valve, generating steam of 40 kg/cm²ga. The cooled HTS is come back to the reactor, respectively.

The lower channels of R-1020A/B are filled with rolled wire mesh to suppressing by-products.

The reactor effluent gas is led to the R-1020A/B gas waste heat boiler (E-1020), where the gas is cooled down to around 240 deg.C and the heat is recovered as steam of 30 kgf/cm²ga.

The HTS electric heaters (E-1052, E-1062A/B) are provided for the heating-up, and for keeping the temperature in case of standby of the reactors, respectively. HTS electric heaters operation is not required after start of IB and MACR reaction.

When the catalyst replacement is carried out, the HTS is discharged to HTS holder (D-1051, D-1061A/B), then reactors are cooled down with cool air by E-1025, the reactors are preheated with hot air heated by E-1025 and hot gas generated by the oxidation reactor start-up furnace (FR-1010) before melted HTS is charged in reactors.

FR-1010 is also used for aeration of 1st and 2nd oxidation catalysts. Aeration is carried out one or two times annually based on catalyst activity.

Nitrogen holder (TK-1009) is provided to supply nitrogen gas to the oxidation system in case of shut down or emergency. It is equipped so that the reaction gas is replaced with nitrogen and purged from reactors to the waste gas catalytic incinerator (R-1030).

Oxygen concentration of the reaction feed gas is decreased by the injection of nitrogen gas from this holder.

2.2 Waste Gas Catalytic Incineration Section

The waste gas is led to the waste gas catalytic incinerator (R-1030) after being heated to around 220 deg.C through the first pre-heater (E-1030A) and the second pre-heater (E-1030C) recovering heat from the combustion gas.

This waste gas catalytic incinerator is a compact rectangular reactor packed with honeycomb type catalyst.

A start-up furnace (FR-1030) is provided at the inlet of the incinerator for heating-up the system and supporting catalytic incineration during the start-up of the oxidation section. No FR-1030 firing is required on normal load operation.

As the result of catalytic combustion, the temperature of the treated gas is raised up to 300 to 400 deg.C at the outlet of R-1030.

Inlet temperature of R-1030 is controlled by adjusting the flow rate through E-1030C by-pass line.

The combustion gas is firstly cooled through E-1030C and the waste gas waste heat boiler (E-1030D), in which heat of combustion is recovered as steam of 2.5 kgf/cm²ga, and lastly it cooled through E-1030A.

Approximately half of the cooled combustion gas is recycled to the first oxidation reactor as an inert dilution gas and to MACR stripping column (T-1130) as the stripping gas through B-1020, and the balance is discharged to the atmosphere as organic free non-pollutant gas.

2.3 HB Separation and MAA Recovery Section

The reaction product gas cooled by the R-1020A/B gas waste heat boiler (E-1020) is introduced into the product gas scrubbing column (T-1110) and quenched to separate HB from the product MAA.

Almost all of HB is condensed into the bottom liquid, and only a small part of the product MAA is condensed into it. In the quenched liquid, there is a suspended solid of terephthalic acid (TPA). So that it is filtered to prevent the deposition to the wall of pipe or column.

The filtrate is fed to the flash evaporators (D-1160, E-1170) to recover MAA into the MACR recovery section and to the MAA extraction section.

The top gas from T-1110, which contains the major part of the product MAA and unreacted MACR is introduced into the MACR absorbing column (T-1120) via the venturi scrubber (S-1110A) and the mist separator (S-1110B).

1) Product Gas Scrubbing Column (T-1110)

The second reactor effluent gas containing MAA, unreacted MACR and impurities (HB, ACD, AA, etc.) is fed to T-1110, where the gas is quenched with large quantity of the HB solution. In this column, the HB is condensed into the bottom liquid, MAA is going through to the top effluent gas. But the separation of HB from MAA is not perfect, so that small part of the product MAA is condensed into the bottom HB solution.

The product gas scrubbing column has 10 stages of perforated tray without downcomer, and is equipped with T-1110 bottom cooler (E-1111A/B/C/D), T-1130 feed pre-heater (E-1135A1/A2/A3) and T-1140 feed pre-heater (E-1145B). The last two heat exchangers are set to recover the waste heat of T-1110. The heat exchangers equipped in this system are of spiral type.

To stabilize the HB solution, hydroquinone (HQ) and phenothiazine (PTZ) are injected to the circulating solution. And also to suppress foaming in this column, antifoaming agent is injected to the circulating solution.

The quenched gas is introduced to S-1110A, where fine solid particles are captured into the HB solution. The HB solution is returned to the T-1110. The effluent gas from S-1110A is led to T-1120 via S-1110B.

In the quenched liquid there is a suspended solid of terephthalic acid (TPA). It is filtered to avoid the problem of the deposition to the wall of pipe or column. This filter is a pre-coat type leaf filter (F-1111A/B).

The filtrate is fed to D-1160 and E-1170 to recover MAA into the MACR recovery section and the MAA extraction section, respectively.

The filtering residue is dissolved with caustic soda and filtered to remove the pre-coating agent via the pre-coating reagent filter (F-1117). This filtrate is fed to the combustion with submerged gas quench (FR-1600) for incineration. And the residue including pre-coating agent is washed out with water and handled by a certified waste treatment company.

2) MAA Recovery Flash Evaporators (D-1160 & E-1170)

Flash system is composed of two stages concentration: the first one is HB cut flash drum (D-1160) and the second one is MAA recovery evaporator (E-1170).

The first one is a vertical flash drum with vertical shell and tube reboiler, and the next one is a vertical thin-film evaporator. The thin-film evaporator is very effective to flash some light-ends from the high viscous fluid.

The bottom liquid of the thin-film evaporator is very viscous. But by diluting it with the raffinate of the MAA extractor (T-1210), it can be transferred easily to the incineration section.

The remained MAA in the bottom liquid of the thin-film evaporator is very small quantity.

In order to stabilize the distillate, hydroquinone (HQ) is injected to condenser (E-1162, E-1172).

3) Oxidation Area Deodorization Column (T-1193)

The vent gas from tanks in this section are sent to the deodorization column (T-1193), and scrubbed with the raffinate of the MAA extractor (T-1210). The condensed liquid from column overhead is sent to incinerating furnace (FR-1510) for incineration.

2.4 MACR Recovery Section

The top gas of T-1110, which contains unreacted MACR and major part of MAA is fed to the MACR absorbing column (T-1120) via S-1110A and S-1110B.

MACR absorbed in the MAA solution is stripped in the MACR stripping column (T-1130) and recycled to the second reactors.

1) MACR Absorbing Column (T-1120)

The exit gas from the S-1110A/B is introduced to the bottom of T-1120, where MACR is absorbed by the cooled MAA aqueous solution.

This column is composed of two sections: the lower section for cooling, provided with a bed of cascade mini-ring (CMR) and the upper section above the chimney tray for absorption, provided with three beds of CMR.

In the lower section, the MACR containing gas is cooled by a large amount of recycling MAA solution of about 35 deg.C and proceeds to the upper absorption section. In the upper section, almost all of MACR is absorbed with recycled bottom liquid of T-1130 chilled to 2.5 deg.C through the MACR refrigerator (RU-1410). The MACR rich solution is taken out from the chimney tray and led to T-1130.

The tail gas of the T-1120 is led to the waste gas scrubber (T-1150). For the elimination of mist entrainment, the mist separator (S-1120) is installed at the top of T-1120.

In order to stabilize MAA in the bottom liquid of T-1120, HQ is injected to the lower section. Also antifoaming agent is injected.

In order to minimize energy consumption in this system, the cold MACR rich solution is heat exchanged at first with the absorbent coming from the T-1130 bottom in E-1131A/B and then with the T-1110 bottom liquid in E-1135A1/A2/A3. Further the absorbent is chilled through RU-1410, and the circulating T-1120 bottom liquid is cooled through E-1121A/B with cooling water. The heat exchangers in this system are plate type.

For the cleaning, the bottom liquid of T-1130 (or DMW) is periodically sprayed to the mist separator (S-1120).

2) MACR Stripping Column (T-1130)

This column is composed of two sections: the lower section for MACR stripping, composed of three beds of CMR packing and the upper section for MAA absorption from the stripped gas stream composed of 10 stages of perforated tray with downcomer.

The MACR rich solution from T-1120 chimney tray after heat exchanging and a part of T-1120 bottom recycling liquid are mixed and introduced to the middle of T-1130 after being pre-heated through the T-1110 second feed pre-heater (E-1135B). In the lower section, MACR is stripped with inert gas sent back from the waste gas catalytic incineration section via B-1020.

For the reduction of MAA content in the recycle gas to be sent to R-1020A/B, the bottom liquid of the T-1150 is fed to the top tray of T-1130 to absorb MAA in the stripped gas from the lower section.

MACR recovered into the stripping gas is recycled to R-1020A/B through the T-1130 top gas pre-heater (E-1132) installed at the top of T-1130.

Majority of T-1130 bottom liquid is come back to T-1120 as absorbing vis RU-1410, some part of liquid is fed to T-1110 to support flushing of MAA at bottom of T-1110, then balance is fed to next column.

In order to stabilize MAA in this column, HQ is injected to the absorbent solution. Also antifoaming agent is injected.

3) Light-Ends Stripping Column (T-1140)

MAA aqueous solution, from T-1120 bottom, T-1130 bottom and the distillate of D-1160, is led to the top of the light-ends stripping column (T-1140), where remaining MACR is removed into distillate. The distillate is led to the feed of T-1130.

This column is composed of three beds of CMR packing, and is equipped with a thermosiphon reboiler (E-1141). This column is operated under reduced pressure of 200 mmHg.

In order to minimize energy consumption in this system, the cold feed solution is heat exchanged at first with the T-1140 bottom liquid in E-1145A and then with the circulating T-1110 bottom liquid in E-1145B.

In order to stabilize the distillate, a part of cooled bottom liquid from T-1130, which contains HQ, is injected to T-1140 condenser (E-1142) and T-1140 vent drum (D-1143).

4) Waste Gas Scrubber (T-1150)

The tail gas from T-1120 is led to the top of T-1150 and washed out with the recycling liquid. The scrubbed gas is sent to the waste gas catalytic incineration section through the T-1150 mist separator (S-1150).

A part of bottom liquid is introduced to the T-1150 bottom liquid filter (F-1151A/B) of cartridge type to remove solid particles such as terephthalic acid (TPA) and filtrate is returned to T-1150, some of which is led to T-1130 top.

This column is installed with a bed of CMR packing.

Antifoaming agent is injected to the bottom recycling line from TK-1124.

For the cleaning of S-1150, purified water is sprayed continuously and periodically.

2.5 MAA Extraction Section

To separate MAA from the MAA aqueous solution, the solution is led to the MAA extractor (T-1210), where a solvent extracts MAA.

The extract is fed to the solvent recovery column (T-1220), where the solvent is recovered as distillate and recycled to the extractor.

The bottom liquid of T-1220 is led to the esterification section as the feed MAA.

1) MAA Extractor (T-1210)

The MAA aqueous solution from TK-1141, which contains MAA of around 40 weight %, is introduced to the top of T-1210.

n-Heptane used as the solvent is fed to the bottom of T-1210 from the solvent tank (TK-1215). MAA is extracted into the dispersed solvent which moves upward in the column.

This MAA extractor is a WinTray column by Japan Gas Corporation.

The extract, which contains MAA and small amount of acetic acid and acrylic acid, is fed to T-1220 via T-1210 Top Receiver (TK-1225) to prevent water contamination.

Water and most of the water solvable by-products are retained in the raffinate, which is incinerated in FR-1510.

2) Solvent Recovery Column (T-1220)

The extract from T-1210 is introduced to the middle of T-1220, where the solvent is separated along with acetic acid and acrylic acid into the distillate and returned to TK-1215.

The ester grade MAA is obtained as the bottom liquid of T-1220, and led to the esterification section via MAA tank (TK-1221).

This column is operated under reduced pressure of 105 mmHg at the top with a steam ejector (J-1223).

This column has 50 stages of perforated tray without downcomer, and is equipped with three units of thermosiphon type reboiler (E-1221A/B/C).

The distillate, composed of the solvent and a least amount of acetic acid, is led to the T-1220 reflux tank (TK-1222), where the distillate is mixed with condensate from J-1223, and the mixture is separated into water and solvent layers.

A part of the solvent layer is recycled to the top as the reflux, and the balance is returned to TK-1215.

The water layer in the reflux tank is led to the T-1220 distillate water phase tank (TK-1223).

To suppress polymerization of MAA in this column, phenothiazine (PTZ) is injected to the column feed line, and oxygen is injected to the reboilers.

3) Solvent Recovery Deodorization Column (T-1293)

The non-condensing gas from J-1223 and the vent gases from tanks in this section are sent to the solvent recovery deodorization column (T-1293), and scrubbed with water.

Water from TK-1223 is utilized as the washing water after cooled down through T-1293 cooler (E-1293).

The condensed water is sent to FR-1510 for incineration.

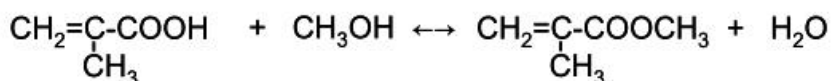
The deodorized waste gas is sent to FR-1510 via the vent gas blower (B-1903) for incineration.

This column is installed with one bed of CMR.

2.6 Esterification Section

The ester grade MMA is produced by continuous esterification of MAA with ME in liquid phase using cationic ion exchange resin as the catalyst in the esterification reactor (R-1310A/B).

The reaction is equilibrium, and the reaction goes to the right hand by the elimination of the reacted products.



Methacrylic Acid(MAA) Methanol(ME) Methyl Methacrylate(MMA)

The effluent liquid from the reactor is led to the MAA separation column (T-1320), where the reaction product and the excess ME are distilled off from the top and MAA is separated into the bottom liquid.

For the removal of high boiling point by-products from the system, a part of the T-1320 bottom liquid is introduced to the heavy-ends cut column (T-1330) and then to the T-1330 bottom evaporator (E-1340).

The distillate of T-1320 is led to the T-1320 top receiver (TK-1322), where the distillate is separated into lighter ester phase and heavier aqueous phase.

The aqueous phase liquid is fed to the ME(MeOH) recovery column (T-1350).

The ester phase liquid is led to the subsequent purification section.

1) Esterification Reactor (R-1310A/B)

In this process, two esterification reactors (R-1310A/B) are provided, in which alternatively one reactor is used.

The ester grade MAA from T-1220 is filtrated through R-1310A/B feed filter (F-1315A/B), and mixed with fresh ME and recovered ME to an appropriate molar ratio.

In addition to the above, the bottom liquid of T-1320 containing unreacted MAA is recycled to the reactor.

The reactant liquid, composed of the ester grade MAA, fresh ME, recovered ME and T-1320 bottom liquid, is mixed homogeneously by the R-1310A/B feed mixers (M-1315A/B), and fed to the top of R-1310A/B.

MAA is continuously esterified in the liquid phase with ME in the presence of cation exchange resin as the catalyst.

The reaction temperature is from 80 to 95 deg. C.

The reactors are of packed bed type with Johnson screen to support the catalyst bed.

To adjust the feed temperature of the reactant, R-1310A/B pre-heater (E-1315A) is provided.

For the purpose of preheating before start-up and cooling down after taken out of service, R-1310A/B pre-heater (E-1315C) is provided.

2) MAA Separation Column (T-1320)

The reaction product liquid is introduced to the bottom of T-1320, where a mixture of MMA and water, as the reaction products, and the excess ME, not containing MAA and high boiling by-products is obtained as the distillate, and the unreacted MAA is separated into the bottom liquid accompanied with MMA.

The distillate condensed through the T-1370 bottom heater (E-1322A) and the T-1320 condenser (E-1322B) is settled in TK-1322, where the distillate is separated into lighter ester phase and heavier ME rich aqueous phase.

The aqueous phase liquid is fed to T-1350, and a part of the ester phase liquid is returned to the column top as the reflux, and the balance is introduced to the light-ends cut column (T-1360).

A part of the bottom liquid is introduced to T-1330, and the balance is recycled to the reactor through the T-1320 bottom receiver (TK-1321) and the recycle MAA filter (F-1321A/B), in which a resin similar to the catalyst is packed.

For the prevention from polymerization, HQ solution from TK-1364A/B is injected to the reflux line and sprayed over E-1322A. Also a part of the distillate is sprayed over E-1322A and the vent condenser (E-1323). Further air is injected to the T-1320 reboiler for the same purpose.

A small amount of acids is contained in the distillate.

To remove these acids by extraction, a part of the bottom liquid of T-1350 is sprayed to E-1322A.

This column has 30 stages of perforated tray without downcomer, and is equipped with a thermosiphon reboiler (E-1321).

The operating pressure is atmospheric.

To recover the latent heat of condensing of the top vapor, T-1370 bottom liquid is circulated as the coolant through shell side of E-1322A.

E-1322A and E-1322B are connected together sharing a common intermediate channel, and the distillate flows through tube side of both heat exchangers.

3) Heavy-Ends Cut Column (T-1330)

A part of the T-1320 bottom liquid, which contains MMA, MAA, and some high boiling point by-products, is fed to the middle of T-1330.

MAA and MMA are recovered as the distillate and fed to TK-1321 after condensed in T-1330 condenser (E-1332).

A part of the distillate is returned to the column top as the reflux.

This column has three beds of CMR packing, and is equipped with E-1332, a vent condenser (E-1333) and a thermosiphon reboiler (E-1331).

The operating pressure of this column is around 60 mmHg at the top.

The bottom liquid is fed to E-1340.

E-1340 is a rotating film evaporator operated under a reduced pressure of around 45 mmHg.

The high boiling point by-products are concentrated in this evaporator, and taken out as waste oil, which is used as auxiliary fuel in the waste water incineration system with dilute agent ME.

The distillate from the evaporator is condensed in a condenser (E-1342), and recycled to the T-1330 bottom.

For the prevention of polymerization in this system, the T-1320 bottom liquid which contains HQ is sprayed over T-1330 bottom and E-1340 vent condenser (E-1343).

Also, HQ solution from TK-1364A/B is sprayed over E-1332, and the distillate is sprayed over E-1332 and E-1333. Further air is injected to E-1331.

As for E-1340, a part of feed liquid is sprayed at the vapor outlet and over E-1342. Also air is injected to E-1340 and the waste oil drum (D-1341).

4) ME (MeOH) Recovery Column (T-1350)

The aqueous phase liquid from TK-1322 is introduced to T-1350 through the T-1350 feed heater (E-1355) together with the aqueous phase liquid from distillate of T-1360.

A mixture of ME and MMA is distilled off from the column top and a part of the distillate, after condensed in T-1350 condenser (E-1352), is recycled to R-1310A/B as the recycled ME, and the balance is returned to the column top as the reflux.

A part of the bottom liquid is utilized as spray water for E-1322A, E-1362 and T-1393, and the balance is discharged as waste water to be treated in outside the battery limit.

This column has 50 stages of perforated tray without downcomer, and is equipped with a thermosiphon reboiler (E-1351), E-1352 and a vent condenser (E-1353).

This column is operated under atmospheric pressure.

For the prevention of polymerization in this column, HQ solution from TK-1364A/B is injected to E-1352, and air is injected to E-1351.

2.7 Purification Section

The ester phase liquid of TK-1322 is purified through light-ends cut column (T-1360) and heavy-ends cut column as final column (T-1370) distillation, and the final product MMA is obtained.

1) Light-Ends Cut Column (T-1360)

The ester phase liquid of TK-1322 is fed to the top of T-1360, where light-ends such as alcohol and water is separated into the top, and crude MMA of almost 100 % purity is obtained as the bottom liquid.

The distillate is condensed in T-1360 condenser (E-1362), where water as solvent from T-1350 bottom is added, and the mixture is led to T-1360 distillate tank (TK-1362), where the distillate settles into two phases: lighter ester phase and heavier ME rich aqueous phase.

The ester phase liquid is returned to the feed as the reflux and mixed through T-1360 reflux mixer (M-1362), and the aqueous phase liquid is recycled to T-1350 for the recovery of ME.

This column has 45 stages of perforated tray without downcomer, and is equipped with a thermosiphon reboiler (E-1361), E-1362 and a vent condenser (E-1363).

This column is operated under atmospheric pressure.

For the prevention of polymerization in this column, HQ solution is injected to the E-1362. Also air is injected to E-1361.

2) Final Column (T-1370)

The crude MMA obtained as the T-1360 bottom liquid is fed to the bottom of T-1370, which is operated under a reduced pressure of 100 mmHg at the top.

The purified MMA is obtained as the distillate, and fed to the product tank through the condenser (E-1372A), distillate cooler (E-1372B), and the distillate filter (F-1372A). A part of the condensate is returned to the column top as the reflux.

The residue from the bottom is led to TK-1364A/B to be utilized as the solvent for inhibitors.

This column has 20 stages of perforated tray without downcomer, and is provided with E-1372A/B, and a vent condenser (E-1373) and a thermosiphon reboiler (E-1371).

Under the normal operating condition, E-1371 is not used, but E-1322A is used as the reboiler for this column utilizing heat of T-1320 overhead condensation as the only heat source for this column distillation.

To stabilize MMA in this column, HQ solution from TK-1374A is injected at the third stage from the top to avoid the product distillate from HQ contamination, and air is injected to the reboiler.

As the inhibitor of the product MMA, AO-30 from TK-1374B is added after F-1372A with cartridge filter.

3) Purification Area Deodorization Column (T-1393)

The vent gases from the esterification section and this purification section are sent to the purification area deodorization column (T-1393), and scrubbed with chilled water.

The deodorized waste gas is sent to FR-1510 via vent gas blower (B-1904) for incineration.

The bottom liquid is transferred to TK-1362.

This column is packed with CMR and operated at atmospheric pressure.

4) Product Tank (TK-1380A/B)

MMA, Product with inhibitor AO-30 is run down to one of product tank (TK-1380A/B). The other side of MMA is sent p-MMA plant and/or shipping tank in OSBL through F-1380 with cartridge filter.

TK-1380A/B has product tank cooler (E-1380A/B) respectively.

2.8 Incineration Section

This process treats 5 kinds of waste solutions and two waste gases, they are the flashing residue of the MAA recovery thin-film evaporator (E-1170), the raffinate of the MAA extractor (T-1210) containing the scrubbing water of the deodorizer (T-1193), the waste water of steam ejector (J-1223), the flashing residue of the T-1330 bottom evaporator (E-1340), the waste gas of the Solvent Recovery Deodorization Column (T-1293) and the last is the waste gas of the Purification Area Deodorization Column (T-1393).

These 7 kinds of waste are burned in the incinerator, and the heat recovery is done through the boiler. Fuel gas is used for maintaining of temperature of FR-1510 as auxiliary fuel via fuel gas holder (D-1560).

1) Incinerator (FR-1510)

The temperature of FR-1510 is kept at approximately 950 deg.C and all organic compounds contained in the liquids are burned directly.

2) Waste Heat Boiler (E-1510A/B/C/D)

The combustion gas is introduced to waste heat boiler (E-1510A/B/C/D) to generate superheated steam and high-pressure steam (E-1510A/C : Generator, E-1510B : super heater, E-1510D : economizer). The outlet gas from the waste heat boiler, which temperature is about 200 deg.C, is discharged to the atmosphere.

3) Raffinate Vaporizer (E-1520A/B)

The raffinate of the extractor (T-1210) is introduced into the falling film type evaporators (E-1520A/B) and concentrated using low-pressure steam. The concentrated liquid is fed to the incinerator through spray nozzles via waste liquid tank (TK-1540), and the vapor from the evaporator is introduced directly into the incinerator.

4) Waste Oil storage Tank & Pump (TK-1550C and P-1550C)

The Waste Oil [the flashing residue of the T-1330 bottom evaporator (E-1340)] can be incinerated both (either) FR-1510 and (or) FR-1600 as per operator's selection with observing the Environment specification. If FR-1600 is under maintenance, the WO-1 can be stored into TK-1550C. And the stored WO-1 can be incinerated additionally after FR-1600 incinerator maintenance is finished.

2.9 Combustion with Submerged gas Quench Section

The residues, which contains fine particles of terephthalic acid, effluent from the HB Separation and MAA Recovery Section is dissolved with the caustic soda solution. After filtering out the pre-coat agents is kept in waste water tank (TK-1920) and the filtrate is incinerated. It cannot be treated in the ordinary type incinerator. If it was incinerated dry type incinerator, its inorganic components would be accumulated in the furnace or would foul boiler heat exchangers. So the Combustion with Submerged gas Quench Incinerator (FR-1600) is selected to burn it completely.

And terephthalic acid is always fouled on equipment and piping inside some of them under operation. These fouling material can be removed by caustic soda easily. These cleaning liquid needs to be treated by FR-1600 due to same reason. Then, the liquid is kept in FR-1600 feed waste water tank (TK-1620) before it is burning in FR-1600.

Fuel gas is used for maintaining of temperature of FR-1600 as auxiliary fuel via fuel gas holder (D-1560).

In this facility, waste gas is directly quenched in the water, so that inorganic compounds e.g. sodium is removed as a Na_2CO_3 solution.

The effluent water from FR-1600 should be neutralized to protect OSBL Waste Treatment System. So the water is introduced to Z-1601, which is equipped with pH analyzer and CSA and CA supplying system. As per the measured pH, CSA or CA is added to control the required pH value. Additionally the waste water from Overall Plant (via TK-1950) is introduced at Z-1601 and neutralized with the Z-1600 effluent water.