SIEMENS

SECTION 1: XPRESS PROCESS DESCRIPTION

1.1 GENERAL OVERVIEW

The Memjet Xpress unit is a complete biological treatment system intended for the treatment of domestic wastewater in housing developments, national parks and commercial applications. The system produces a high quality effluent that can be used for reuse applications such as irrigation, water recharge and non-portable water applications. The Xpress Membrane Operating System Biological Reactor (MBR) plant has a total capacity of 50,000 gpd average daily flow with peaks up to 100,000 gpd. The MBR processes used in sequence are as follows:

- primary treatment using fine screening (2mm perforated plate drum screen)
- biological nutrient removal including anoxic (denitrification) zone and aerobic (nitrification) zone with dissolved oxygen control
- membrane operating system (MOS) for filtration

The Memjet® Xpress system has been designed to treat typical domestic wastewater as detailed in the table below.

PARAMETER	UNITS	VALUE
BOD (COD)	*mg/L*	250 (500)
TSS	*mg/L*	250
TKN	*mg/L*	50
NH_3-N	*mg/L*	33
pH		7
Alkalinity	*mg/L*	300
Temperature	*°C (°F)*	10 - 30 (50 - 86)
MLSS in aerobic zone	*mg/L*	10,000

The effluent quality is based on the influent concentrations as detailed above. The Xpress system is able to produce effluent with the following quality:

PARAMETER	UNITS	VALUE
BOD	mg/L	< 5
TSS	mg/L	< 5
Total Nitrogen (TN)	mg/L	< 10
Turbidity	NTU	< 0.2
Fecal Coliform	MPN/100 mL	< 10

The purpose of this document is to outline the operation of the complete Xpress Process.

1.1.1 PRE-SCREEN

The 2mm perforated plate rotating drum screen is used to remove of any fibrous material in the influent before it enters the Xpress system. The pre-screen is rated for the peak flows of the system as stated above which is typically two times the average daily flow.

Screenings rejected by the fine screen will fall from the screen via a chute into a hopper or compactor which when full is removed from the site to a solid waste handling facility.

In addition to screening the influent, the screen is also used in the re-screening process. Re-screening returns a portion of mixed liquor, typically one to two times the average daily flow, back to the pre-screen during periods of low influent flow

1.1.2 BIOLOGICAL PROCESS

The biological process is an activated sludge treatment system designed for the degradation of organic contaminants, ammonia and nitrates from a typical wastewater. The Xpress system consists of a single train configured with two zones in series with an internal recirculation loop.

The degradation for the organics is due to mirco-organisms (bugs) that are present in activated sludge. These micro organisms are able to metabolize contaminants in wastewater. Dissolved wastes are consumed as food by the activated sludge microbes and converted to water, carbon dioxide and biomass.

In addition to the organic degradation, nitrogen compounds, such as ammonia, are converted into nitrates by the nitrification process. These nitrates are then further broken down into nitrogen gas by the denitrification process.

The biological system also includes chemical dosing for nutrient removal such as;

- Alum dosing for phosphorous removal
- Sodium hydroxide for pH or alkalinity adjustment
- Potassium acetate (carbon source addition) for improved denitrification conditions.

1.1.3 MEMBRANE FILTRATION

The Membrane Operation System (MOS) for the Xpress unit provides an absolute barrier to all micro-organisms and suspended solids greater than 0.1 micron in size. Thus, retaining all bacteria, flocculates, suspended solids and some viruses in the biological system and producing a high quality effluent.

The MOS replaces the secondary clarifier and sand filter of a conventional wastewater treatment plant decreasing the footprint requirements of the system. The absolute barrier of the membrane also provides a guaranteed solids content in the effluent regardless of the biological system operation, i.e. there is no settleability issues.

1.2 PRE-SCREENING DESCRIPTION

The purpose of this section is to outline the components that make up the Pre-screening and re-screen operation for the Xpress system.

1.2.1 WHY FINE SCREEN?

Fine screening is critical to the operation of any membrane system. Gross solids such as fibrous material or plant material (sticks and leaves) can easily become trapped in between the fibers and cause solids accumulation. As the solids accumulate in and around the top of the membrane module, two major effects can be seen. Firstly, the solids decrease the amount of movement in the fiber, critical for the removal of the filter cake that forms on the surface of the membrane. Secondly, the gross solids may have sharp edges or other abrasive properties that either damage or puncture the surface of the membrane fiber.

In terms of operational performance this equates to

- Decreased membrane life (more frequent repair and/or replace of modules)
- Increased trans-membrane pressure (TMP) (increased power cost)
- Decreased duration between chemical cleaning (increased chemical costs)
- Increased operator maintenance

1.2.2 FINE SCREEN DESCRIPTION

The fine screen provided as part of the Xpress system is a 2mm perforated plate rotating drum. The perforated plate is used sue to the fibrous material removal required.

The rotating screen has internal and external nozzles that spray down the perforated plate drum periodically to clean it and prevent the build-up of solids causing the screen to "bind up". The interval of the spray water is site specific and is depend on the amount of solids in the influent feed. The duration of the spray water is typically 65 seconds as this is time for a single full rotation of the drum

1.2.3 RESCREENING

The purpose of re-screening is to remove any fine solids that may agglomerate or join together in the biological system and cause gross membrane fouling (solids accumulation).

Re-screening returns a portion of mixed liquor, typically one to two times the average daily flow, back to the pre-screen during periods of low influent flow. Re-screen is performed during periods of low influent flow so as no to disrupt the normal operation of the Xpress system. The portion of mixed liquor is returned to the headworks via the recirculation pump.

1.3 Biological system description

The purpose of this section is to outline the components that make up the Biological system description for the Xpress system.

1.3.1 WHAT IS AN ACTIVATED SLUDGE SYSTEM?

Activated sludge is a mass of many different micro-organisms that are present in most biological treatment systems. The process conditions such as

- Temperature
- Presents of dissolved oxygen
- Nutrient concentrations – ammonia, nitrates, phosphorous
- pH of the wastewater and alkalinity
- organics content measured in BOD
- SRT & HRT

play a significant role in the types of bugs that will be present in an activated sludge system.

On the most basic level, the bugs use carbon present in the wastewater, as organic compounds, as food and combine with oxygen to them energy and produce carbon dioxide, CO_2, as a waste product.

C (Carbon source) + O_2 → CO_2 + energy

This decreases the BOD of the water exiting the plant, this helps to protect the local water ecology by not starving the water of oxygen.

1.3.2 BIOLOGICAL NUTRIENT REMOVAL

Nutrients in the effluent can also affect the discharge waterways by the growth of algae's. The main nutrients are nitrogen compounds in the form of ammonia, nitrates and organic nitrogen. These components are broken down in a process called Nitrification/ Denitrification that is explained below.

3.2.3.1. Nitrification (aerobic zone)

In the nitrification process, autotrophic organisms use ammonia as food to oxidize it to nitrates in the following two stage process;

NH_4 + 3/2 O_2 → NO_2 + H_2O + 2H+ + new biomass

NO_2 + ½ O_2 → NO_3

In order for nitrification to occur the following requirements must be met:

- Alkalinity Requirement – 7.1 lb (as $Mg(OH)_2$)/ lb NH_2-N nitrified is required.
- Oxygen Requirement – 4.6 lb/lb NH_2-N nitrified is required.

SRT Requirement – depending on temperature a minimum SRT is needed to ensure growth of nitrifying organisms.

3.2.3.2. Denitrification (Anoxic zone)

Denitrification is a process where heterotrophic organisms convert nitrates and nitrites to gaseous end products, primarily nitrogen gas. This is an "anoxic" process (not in the presence of dissolved oxygen) and is dependent upon maintaining a very low DO condition. The following equation shows the mechanism of denitrification;

$NO_3^- \rightarrow NO_2 \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Some treatment plants are required to remove nitrogen, but there are reasons to partially denitrify even when not required. Low alkalinity water tends to decrease pH rapidly during nitrification because of the alkalinity consumed in this process. Denitrification recovers some alkalinity consumed during nitrification, so it can be used for pH control.

A plant must be nitrifying in order to denitrify, sufficient oxygen, alkalinity and SRT are required to switch nitrification on. Once this occurs denitrification can provide the following process and economic benefits:

- Alkalinity recovery – 3.6 lb/lb NO3-N denitrified
- Oxygen recovery – 2.9 lb/lb NO3-N denitrified

1.3.3 BIOLOGICAL SYSTEM DESCRIPTION

The following diagram is a representation of the biological system for the Xpress unit. As can be seen it consists of two tanks, the aerobic and anoxic zones. The "Q" value represents the design average daily flow for the plant.

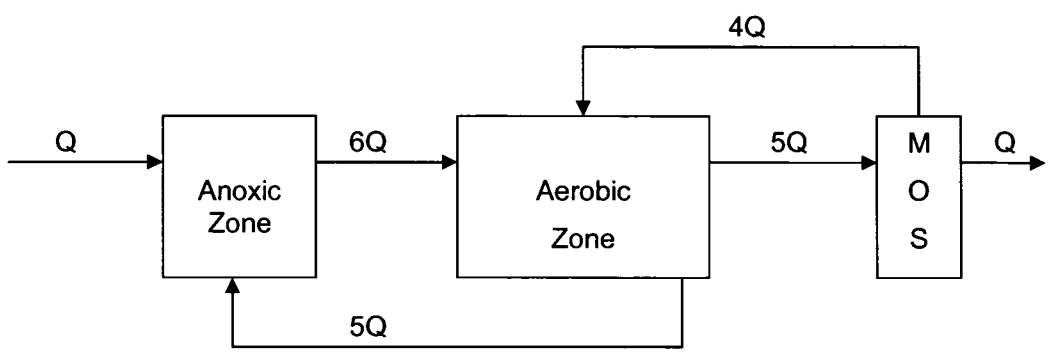


Figure 1: Biological system diagram

After the screened influent drops into the aerobic zone it mixes with activated sludge returned via the recirculation pump to this tank.

The micro-organisms use the carbon found in the organic components and the oxygen in the nitrates from the mixed liquor producing energy for the microbe and nitrogen gas (as detailed above) that goes to atmosphere.

This occurs relatively quickly with the average microbe staying in the anoxic zone for just 0.58 hours (Anoxic HRT). The anoxic zone must be kept at a low DO concentration ~ 0mg/L, so that the micro-organisms use the oxygen bonded to the nitrates instead of free oxygen.

The mixed liquor then overflows via a weir into the aerobic zone. In this zone, the remaining organisms to produced carbon oxygen, CO_2, that bubbles off to atmosphere. In addition to organics degradation, the oxygen is used in the nitrification process where ammonia is broken down in the presence of oxygen to produce nitrates (as detailed in section 2.3.2).

Although nitrifying micro-organisms are quicker to acclimatize to an environment, the nitrification process occurs at a slow rate, as such the hydraulic retention time (HRT) for aerobic zone is 7.82 hours.

The oxygen for the system is supplied by air pushed in the system through the use of a positive displacement blower. Fine bubble diffusers, membranes with small slits, distributes the air across the whole aerobic zone in small diameter bubbles. These small bubbles allow increased oxygen transfer efficiency.

The mixed liquor is then directed to the mixed liquor feed pump and the membrane system.

The main components of the biological system for the Xpress include:

- One (1) biological positive displacement blower with VFD
- One (1) recirculation pump with VFD (end-suction centrifugal from aerobic zone to anoxic zone).
- One (1) submersible mixer

1.3.4 BIOLOGICAL TANK DESCRIPTION

The biological tank is a cylindrical tank of 12ft diameter (painted carbon steel) divided into two zones by an internal baffle wall.

Each zone is sized to give the hydraulic retention time stated above, such that the volumes are;

Anoxic Zone: 7,456 gals (28,224 L)

Aerobic Zone: 13,545 gals (51,273 L)

The aerobic zone contains 36 fine bubble diffusers to distribute air across the entire tank as well as the headers and supports for the diffusers.

1.3.5 DISSOLVED OXYGEN CREDIT

Membranes require an air scour to prevent solids accumulation on the surface of the membrane; this requires a significant amount of air entering the system. As such the mixed liquor exits the membrane tanks nearly completely saturated with dissolved oxygen. This dissolved oxygen is used in the aeration zone to supplement the oxygen supplied by the biological blower. This dissolved oxygen is calculated based on the following calculation;

O2 Credit = $DO^* \times Q_{overflow}$

DO^* = the saturated dissolved oxygen concentration at a given temperature (mg/L)

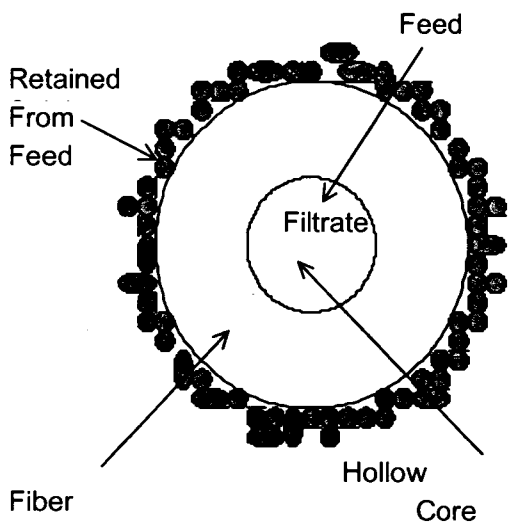
$Q_{overflow}$ = The flow entering to the aerobic tank via the membrane overflow weir (L/day)

1.4 Membrane Operating System Description

The purpose of this section is to outline the components that make up the Membrane Operating System (MOS) for the Xpress system.

1.4.1 WHAT IS A MOS?

MOS is the short name for the Membrane Operating System. Membrane filtration removes particles greater than 0.1 microns from a mixed liquor feed stream. The MOS unit uses hollow fibre membranes in a self-cleaning system and utilises a proprietary two-phase Jet Scrubbing system. The Jet Scrubbing provides sufficient turbulence to ensure the solids do not build-up on the membrane surface, and it consists of two main processes: FILTRATION and RELAXATION. Details are described below.



Cross-section Through A Single Fiber During Filtration

Filtration

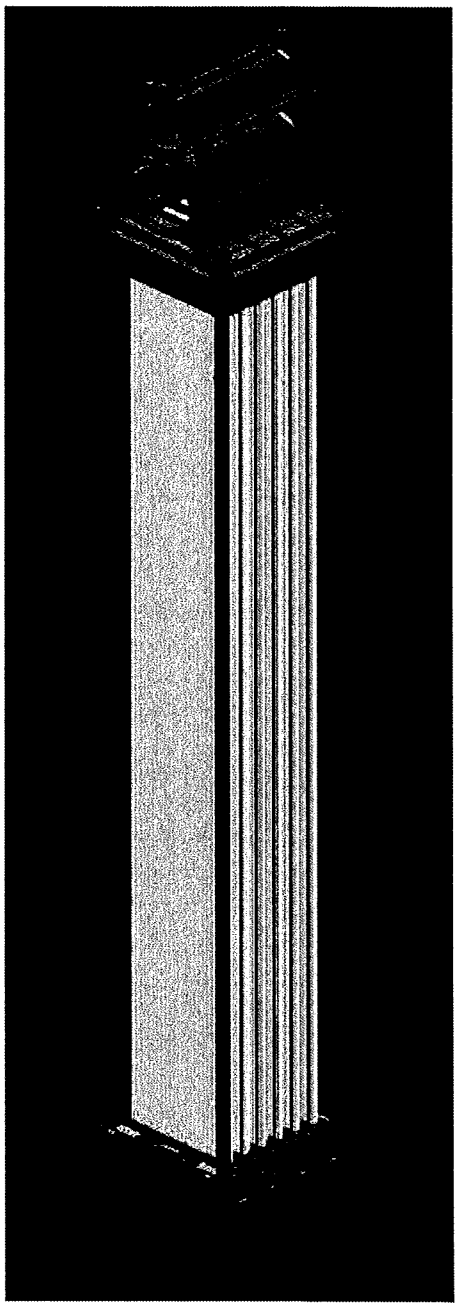
FILTRATION takes place from the outer surface of the fibre to the hollow inner core or lumen (outside in). A filtrate suction pump applies suction to the inside of the membrane fibre. Feed liquid passes through the porous wall of the fibres under suction, while the solids in the feed stream are retained on the outside of the fibre wall. A combined jet flow and air scrubbing action provide a shear force on the surface of the membrane to control solids build-up.

Relaxation

The cross flow created by the MemJet and Scour air is effective at preventing solids build-up on the surface of the membrane during FILTRATION. However, the jet scrubbing action effectiveness is enhanced when the unit is not filtering, i.e. in RELAXATION, as there is no driving force of solids onto the surface of the membrane. The MOS unit stops after a set time of FILTRATION to perform a RELAXATION step. This allows for the filter cake to relax and decompress, which improves the efficiency of the jet scrubbing action.

1.4.2 THE B30R SUB-MODULE

The main component of the Xpress MOS is the B30R sub-module. The sub-module forms a serviceable filter element that can be removed for repair or replacement.



Each sub-module contains thousands of hollow fibre made from chlorine-resistant PVDF sealed with polyurethane "pots" at both ends. The top pot allows filtered water to pass from the hollow inner core or lumen of the membrane fibres to the filtrate manifold. The bottom pot seals the ends of the fibres but allows low-pressure process air and mixed liquor to pass through a series of holes or "slots" into the fibre bundle and around the fibres during operations including Filtration, Relaxation and Maintenance Clean.

The B30R Sub-modules are connected to a rack assembly manifolding 5 submodules together. The modules are attached to the headpieces with stainless steel bolts which slot into the four corners of the headpiece. The o-ring provides a tight seal so that no by-pass can occur.

The modules have "skirts" attached underneath the bottom potting; these are attached to the modules using clips that are integral to the skirts. The skirts are constructed from a derivative of nylon and are created by inject molding.

The air nozzle is attached to the headpiece by a clip and slotted into the skirt through the guide on the side of the skirt. The air nozzle is constructed from PVC pipe. This air nozzle delivers the scour air to the bottom of each module.

1.4.3 MOS DESCRIPTION

The Mixed Liquor (ML) is drawn from the aerobic zone of Biological system and pumped into one of two membrane tanks through a common ML feed pump. Once the ML enters the membrane tank it is directed into a ML feed manifold & lateral system.

A single Filtrate Pump is provided for both membrane tanks and applies a vacuum or suction pressure for filtration. The produced filtrate from each membrane tank is manifolded together, through the filtrate pump and is directed either into the downstream Filtrate Storage Tank or discharge out of the Xpress system or downstream operations.

The main components of MOS for the Xpress system include:

- One (1) ML Feed pump (end-suction centrifugal pump from aerobic zone of the Biological system) sized to provide mixed liquor for two membrane tanks;
- Two (2) x Membrane Tanks;
- One (1) Filtrate pump sized for producing the total flow from the plant;
- One (1) x MOS Scour Air Positive Displacement Blower sized to provide air for two membrane tanks;
- One (1) Chlorine Dosing System/ One (1) Citric Acid Dosing System;

1.4.4 MOS TANK DESCRIPTION

The MOS tank is a rectangular tank (painted carbon steel) which houses the B30R rack assemblies. Five (5) B30R submodules are assembled together forming an integral rack assembly, and the rack assemblies are then connected to the MOS cell Filtrate manifold and the Scour air manifold (or header). The numbers of rack assemblies in each tank are set to suit the designed flow requirement. O-rings create watertight seals between the different wetted components.

Overall each MOS tank comprises:

- One (1) MOS tank ML feed manifold and lateral system consisting of two lateral each with 5 jet nozzles;
- Two (2) installed removable MOS rack assemblies to each connects five (5) B30R sub-modules;
- One (1) Cell Air and One (1) Filtrate Header;
- Rack support rails and rack guides;
- Frontal pipe work, valving, instrumentation and local controls.