ARR Re-Refining System®
Base Oil & Fuel Recovery System

For Re-Refining Waste Oils
AGC Refining & Filtration developed an innovative process to recover base oil and light ends from waste oils — typically used crankcase oils, used lubricants, or marine slops.

The ARR System will preserve, in some cases enhance, the physical and chemical properties of both mineral and synthetic base oils. The process uses no chemicals and has no atmospheric process emissions and can be a net zero energy system. The ARR technology is a solution to the global environmental problem of burning waste oils.

The recovered base oil will retain the physical and chemical characteristics of the virgin base stock, specifically the percentage of Saturates, Paraffins and Polyalphaolefins (PAOs) count and Viscosity Index, as confirmed by ASTM tests.

**The ARR is a proprietary vacuum distillation system that employs a low temperature fracturing process.**

**The ARR targets precise boiling points to separate the feedstock’s constituent parts: water, fuels, base oils and asphalt enhancer.**

**The ARR does not use chemicals or catalytic-, thermal- or hydro-cracking in any form, and has no atmospheric emissions.**

**The system is modular and multiple lines may be added to increase throughput and volumes.**

**The ARR is a fully automated, continuous system (not a batch process) and requires no down time. A single HMI controls the entire system.**

**The ARR system does not require standardized feedstock or separated waste oils.**

**The ARR system is a totally closed system eliminating operating odor and accidental exposure of fluids or gasses to the work environment.**
Figure 1 Full-scale The layout of ARR System Components: Components shown: ARR distillation skids, trunnion vessels
Basic Description of AGC Re-refining System (ARR) to recover base oil and fuels from waste oils

The ARR uses a series of simple, highly effective systems which employ the principals of heat, vacuum distillation, refrigeration condensing to purify oils of particulate contaminants, water, air, gases, solvents, acidity, and other light hydrocarbons or volatile impurities, and pressurized cartridge filtration for removal of odor and color.

Each distillation skid unit is designed for a flow rate of not less than 1,500 liters per hour. Achievable operating vacuum shall be 1-25 mm Hg or less to provide efficient dehydration and degasification at 80° - 110° C.

**OIL INPUT**

The oil is pumped into the Oil Conditioner through one of three (3) ball valves (XEV5720A, B, or C) by a motor driven pump supplied by the customer.

**PRIMARY FILTRATION**

Under pressure, the waste oil fills the filter vessel until all air is evacuated and it is forced through the disposable filter cartridges. Pressure indicators are mounted on the filter.

**DUAL-FIRED FURNACE**

A dual fired furnace process heating system is used so fuels from the re-refining process, diesel, or propane or natural gas to operate the plant. Generally a portion of the light ends (fuels) produced by the ARR are sufficient to provide adequate fuel needed.

**VACUUM DISTILLATION**

The oil, still under pressure from the customer’s pump, flows to the vacuum vessel. A level transmitter controls the oil level in the bottom of the vessel. From time to time throughout the normal operation of the system, the oil level in the vessel fluctuates. The oil flows into the top of the vacuum vessel through a disperser ring. It then flows by gravity over a proprietary vacuum vessel allowing the contaminants to be drawn off as vapors or gases by the vacuum pump. This process is continuous through a series of dedicated distillation skid units for each distillation, to produce each desired product.
OIL OUTPUT

Oil is drawn from the vacuum vessel by a motor driven gear recirculation pump with a pressure relief valve. A constant flooded suction enables the pump to pull a full vacuum at the rated flow of the system.

VACUUM PUMP

The unit is equipped with a high-quality vacuum pump. This unit consists of a liquid ring sealed vacuum pump.

There are generally nine sections to the ARR Re-refining System:

1. **AGC ARR Skids** – involves heat exchangers, vacuum vessels and condensing vessels to remove water, light ends and fuel oils, and base oils. The number of skids is based on the process volume and number of desired virgin quality products.

2. **AGC Trunnion Bulk System** – removes color, acidity, and sulfur.

3. **AGC Filtration Skids** – removes additional color and sulfur as well as fine particulates.

4. **Thermal Heating System** – heats high temperature heating oil for efficient system heat need without indirect coking or a necessity to use a specific fuel source.

5. **Glycol Chilling System** – will return all distillate to a temperature required to return it to a liquid state.

6. **Vacuum Exhaust Scrubbing Unit** – is for cleaning the vacuum pump exhausts, which contains high levels of hydrogen sulfide and 100 percent of dissolved and entrained gasses.

7. **Wastewater Treatment System** – takes water removed from the dewatering phase, combines it with neutralized liquid from the exhaust scrubbing phase to produce irrigation, marine, or discharge standards.

8. **Human Machine Interface (HMI)** – is designed to operate, manage, and troubleshoot the AGC Re-Refining Plant with minimal man power, maximum automation, and extensive safety controls.

9. **Blending System (optional)** – with the addition of additives, this system will produce customer-specific oil products from the recovered base oil through a blending and additive system.
1 Plant Overview
The ARR system is designed for minimally attended, automatic operation except for the normal attention required during start-up, shut-down, and maintenance. All vessels are constructed according to the ASME Boiler & Pressure Vessel Code Section VIII Division I and will be UNSTAMPED unless “U” stamp option required.

The ARR consists of nine sections to complete a continuous refining system as shown in this piping and instrumentation diagram (P&ID):
1.1 AGC RE-REFINING SYSTEM COMPONENTS

Carbon steel ARR System:

- This modular system is designed to use vacuum distillation to remove water down to less than 10 wppm. It will separate fuels to a specific qualification which could include solvent kerosene, various light ends including diesel, burning oils from MGO to HFO and various cuts of base oil from group I to III.
- This system is a skid-mounted with interconnecting plumbing. It is designed with a compact staged design to maximize heat retention and reduce energy consumption, yet allowing modular expansion for volume or finished product requirements without needing a new plant.

- Each skid will contain the following:
  - One Vacuum Vessel to create the necessary surface area to allow distillation
  - One Heat Exchanger to heat the incoming feedstock
  - One Distillate cooling system to condense the vapor stream back into a liquid
  - One Condensation Vessel with pump and motors to move the water and light ends/fuel oils to tank storage (and lubrication oil to the clay filtration system)
  - Two Pumps and Motors – One inlet and One outlet
  - One Vacuum pump for vacuum distillation of water, fuel oils, and base oils.

*Latin American Installation in Process*
### 2.1 AGC RE-REFINING SYSTEM

The vessels use vacuum distillation for separating multi-component oils into individual compounds. Mass transfer occurs due to a difference in concentration, in which the random motion of molecules causes a net transfer of mass from high to low concentration. Mass-transfer occurs at the interface between vapor and the liquid film that covers the packing surface. The mass-transfer is significantly affected by the specific area of the packing.

The vessels use proprietary components and configurations to facilitate mass-transfer maximizing the operating range of the vessel to achieve the best performance, minimizing the pressure drop for each stage of separation, and maximizing the number of stages included in the height of the packing. As the fluid flows from the distributor ring onto the integral components of the vacuum vessels there is maximum surface area, allowing for maximum mass-transfer.

#### 2.1.1 Vacuum Vessel –

Vacuum vessels are made of carbon steel and in accordance with ASME Standards. The vacuum vessel is where the contaminants are vaporized by high temperature and high vacuum, using the commonly applied physical engineering process of Vacuum Distillation.
The vacuum lowers the boiling point of the fluids and promotes vaporization at lower temperatures than without a vacuum. Making it safer to manipulate and process.

The vacuum vessel internals consist of a proprietary and patented configuration of components that promotes efficient mass-transfer that vaporizes the liquids. Four level switches control the level of the clean fluid in the bottom part of the Vacuum Vessel.

2.1.3 Plumbing –

All interconnecting plumbing within the skid is pre-welded. The plumbing is made from carbon steel, two inch schedule 40 pipe. Flanges and automated ball valves are located at each major component to facilitate disassembling connections. All plumbing is modular, computer controlled, and flanged. The flanges are numbered for ease in assembly.

2.1.4 Condensate Vessel –

Condensate vessels are carbon steel, sealed vessels smaller than the vacuum vessels. This is where the distillate vapors get stored and condensed.
2.1.5 Pumps –

The inlet and outlet pumps are high-speed, high temperature, heavy-duty pumps. These pumps can be directly connected to a 50 Hz or 60 Hz motor. These pumps are furnished with a single mechanical seal. The seal is a simple self-adjusting, non-leak method of shaft sealing. These pumps are built for continuous or intermittent duty for filtering, circulating, or transferring.

The pumps are equipped with inner casing ball bearing installed outside of the mechanical seal and a radial thrust ball bearing permitting heavy-duty service. A pressure lubrication system automatically lubricates the idler bushing. This system provides a constant film of liquid between the idler bushing and idler pin at a pressure equal to the pump discharge pressure regardless of pump rotation.

O-Ring gaskets are used between casing and head plate and between casing and relief valve. Gaskets provide a positive seal eliminating a chance for leakage at these points.

These pumps are positive displacement type which are ideal for variable motor speed applications.

The pumps are controlled by a PLC and each has an Variable Frequency Motor Drive, which is used to adjust the motor speed to oils of various viscosities, and to balance the entire plant.

2.1.6 Vacuum Pumps –

The ARR system uses liquid ring pumps for the Vacuum Distillation Systems. The vacuum mechanism is a multi-blade impeller on a shaft is positioned eccentrically in a cylindrical housing that is partially filled with sealing liquid. The blades enter the liquid ring at decreases and increases depths as the impeller rotates, creating a
vacuum. The mechanism is rugged and can withstand severe duty. It compresses the gas and expels it through the exhaust valve and passes gas contaminates to the exhaust scrubbing system. Liquid ring pumps are reliable and have a proven long lifetime.

2.1.7 Controls –

The Programmable Logic Control (PLC) is located on each skid. This allows for efficiency and easy access. It controls the heaters and pumps. Variable frequency drives are also located on each skid to provide immediate adjustment of skid motors and components. Each skid is connected by a single Ethernet cable to the main control HMI. Each skid is connected by a single Ethernet cable to the main control HMI.

Figure 5 Programmable Logic Control

Figure 6 Main Control HMI
2.2 AGC TRUNNION BULK SYSTEM

These vessels hold 1500 pounds of clay filtration media. Configuration comes in pairs of 2 to 12.

2.2.1 Vessels –

AGC Trunnion Bulk System vessels are carbon steel and designed for efficiency and ease of operation. These vessels are constructed to ASME Standards. The covers are held in place by swing bolts and nuts, designed so that complete removal of the nuts is unnecessary for removal of the cover.

2.2.2 Clay Media –

The media uses inherent properties to adsorb acids and remove color from oils. This media has a unique ability to capture molecules of surfactants. Each particle consists of a lattice work of microscopic passages. The large surface area allows the particles to capture surfactant molecules.
2.2.3  Removing Media –

When the media is spent, the vessel can be tilted on its side to allow easy clean-out. The lifting and tilting gantries allow for single operator, efficient clean-out.

Figure 9 Trunnion vessels tilt for easy clean out.

2.3  AGC FILTRATION SKID

AGC Filtration Skids are designed in an array of types and sizes to meet the specific needs of your situation. The AFM comes in duplex or simplex models and used a variety of filter elements. The main elements are stacked disks and media elements.

Duplex allows for continual operation while contaminated filters are being replaced. Different pressure switches recognize consumed vessel filters and automatically shift flow to the unused duplex vessel.

Figure 10 AGC Filtration Skid
2.3.1 Vessels –

The vessels are built to ASME standards.

The vessel covers are held in place by swing bolts and nuts, designed so that complete removal of the nuts is unnecessary for removal of the covers.

Each vessel contains a number of standpipes that correlates to the number of filter elements per customer needs. These standpipes are on a false bottom. The standpipes are the perfect diameter for AGC filter elements. The filter elements fit and slide down the standpipes with a spring cap on top to hold them down.

Bypass filter vessels are designed to provide relatively slow, but very fine filtration by passing all or a portion of the fluid in a system through solidly packed, depth-type elements (media elements).

Full flow filter vessels are designed to purify all the liquid in a system by passing it through full flow, surface-type elements such as solids filters.

A final polishing skids removes any remaining filtration media that may have passed through the filtration process.

2.4 Thermal Heating System

This thermal oil heater is designed with double helical coils for liquid flow configurations. The standard configuration is series flow with the oil entering the first coil, passing to the end and coming back through the second coil.
2.4.1 Heater –

The heater consists of two coils inside a shell heated by a burner with the associated controls. The heater fuel source is everything from pure diesel to light ends to propane or natural gas to minimize energy costs and eliminate process byproducts.

2.4.2 Coils –

The dual coil is the heat transfer section and is fabricated to the design requirements of ASME section I. The coil welds can be tested by x-ray. The coil is hydrostatically tested at a minimum of one-half times its design pressure. The coil is sized to produce low film temperatures at acceptable pressure drops. The standard heater coil usually has a maximum radiant heat flux rate of approximately 10,000 BTU/hr/ft.

2.4.3 Shell –

The shell is a single cylinder of welded construction. The standard shell is externally insulated with three inches or more of 900°F rock wool blanket insulation which produces an average skin temperature of 140°F when fired at 550°F outlet temperature (or less), an ambient temperature of 70°F and an air velocity of 1.5 feet per second.

2.4.4 End Plates –

The heater end plates are fabricated and internally insulated with six inches of ceramic fiber blanket insulation. The front end plate generally has a refractory combustion block of 3000°F to 3300°F material. The rear end plate has a viewing port. Seal plates are bolted around the coils entrance and exit from the shell. The removable end covers are sealed and bolted to the shell. The coil nozzles are sealed to the end plates. This allows for coil removal if ever required.
2.4.5 Burner –

The forced draft burner on double helical coil units and the atmospheric burner for straight tube units are selected to provide the required input for the fuel(s) to be used.

2.4.6 Expansion Tank –

This allows for the expansion of the liquid from a cold state to operating temperature. It should be used in conjunction with an inert gas blanket or a cold seal tank. The minimum level in the expansion should be at least 6 inches (150mm) above the highest point in the circulation system.

2.5 GLYCOL CHILLING SYSTEM

The microprocessor controlled, air-cooled liquid chiller for outdoor installation, utilizes scroll compressors, had low sound fans and option hydronic pump system.

2.5.1 Materials or Construction –

Base rail is industrial-quality, 7ga, zinc-dipped, galvanized frame

Cabinet shall be galvanized steel casing with a baked enamel powder or pre-painted finish.

2.5.2 Fans –

Condenser fans shall be direct-driven (VFD) controlled, 9-blade airfoil cross-section, reinforced polymer construction, shrouded-axial type, and shall be statically and dynamically balanced with inherent corrosion resistance.

Air shall be discharged vertically upward.

Fans shall be protected by coated steel wire safety guards.
2.5.3 Compressor/Assembly –

Fully hermetic scroll type compressor

Direct drive, 2500 rpm, protected by motor temperature sensors, suction gas cooled motor.

External vibration isolation rubber-in-shear.

Each compressor shall be equipped with crankcase heaters to minimize oil dilution.

2.5.4 Cooler –

Shell-and-tube type, direct expansion.

Tubes shall be internally enhanced seamless-copper type rolled into tube sheets.

Equipped with Victaulic-type water connections

Shell will be insulated. PVC foam with a maximum K factor of 0.28.

Design will incorporate a minimum of 2 independent direct-expansion refrigerant circuits.

Cooler shall be tested and stamped in accordance with ASME code.

2.5.5 Condenser –

Coils shall be air-cooled. Novation heat exchanger technology with microchannel coils and shall have a series of flat tubes containing a series of multiple, parallel flow microchannels layered between the refrigerant manifolds. Coils shall consist of a two-pass arrangement. Coil construction will consists of aluminum alloy.

Tubes will be cleaned, dehydrated, and sealed.

Assembled condenser coils are pressure tested at 656 psig.
2.5.6 Refrigeration Components –

Refrigerant circuit components shall include replaceable-core filter drier, moisture indicating sight glass, electronic expansion device, discharge service valve and liquid line service valves, and complete operating charge of both refrigerant and compressor oil.

2.6 VACUUM EXHAUST SCRUBBING UNIT

This unit takes the exhaust from the vacuum and through a vertical packed tower scrubber configuration and diverts the exhaust to a neutral liquid instead of the atmosphere.

This unit removes hydrogen sulfide and all entrained and emulsified hazardous gases to the waste water treatment plant, which reduces the toxic atmospheric emissions into usable or discharge water.

2.6.1 Vertical Pump –

This pump features a cantilevered, sleeved stainless steel shaft which eliminates bearing or bushing resulting in a chemical duty pump which can run dry indefinitely, providing years of trouble free service. The compound impeller prevents liquid from rising in the column, even at maximum TDH, while the semi-enclosed bottom impeller provides efficient flow performance at low horsepower.

2.6.2 Polypropylene Packing –

Similar to the vacuum vessels, this scrubbing unit uses random-style packing for the same reason. It allows for increased surface area, thus giving the most efficient outcome.

The scrubbing unit uses plastic packing rings that are spherical in shape. This round shape offers reliable and predictable loading of your tower which means reliable and predictable performance. In addition to the superior geometric shape, an
active surface area is vital to mass transfer. These rings have a distinct advantage in providing excellent wetting qualities and maintaining liquid distribution through the packed bed. They offer optimum surface area to open area ratio which yields excellent mass transfer efficiency and reduced operating costs.

2.6.3 Liquid Level Float Switch –

The level float switch is designed to monitor up to six levels on a single device. With only one single entry, the switch can track changing levels within a large tank, as well as monitor liquid interfaces of dissimilar liquids for oil/water separation, chemical emulsions and condensation levels.

2.6.4 Universal Dual Analyzer –

This analyzer is a new, economical, dual input analyzer. It accepts single or dual inputs, contacting conductivity and dissolved oxygen sensors. It monitors and controls analytical process variables.

2.7 WASTE WATER TREATMENT

Waste Water Treatment System is for cleaning the waste water stream, as well as the inert liquid from the air-scrubbing unit, to irrigation quality discharge.

2.7.1 Pneumatic System –

Compressors: are loaded with features designed for day-in, and day-out performance. The compressor’s unique automotive-type domed piston design allows the use of large diameter, low lift valves, while minimizing clearance volume for maximum air delivery. The compressor features slow speed operation, rugged cast iron crankcase
construction, corrosion resistant steel valves and tapered roller-type main bearings, all contributing to long life.

Air treatment dryer: has four levels of intelligence controller packages to allow customization. Specific heat exchangers ensure you get the right combination of value and efficiency in every size, securing your investment. Combination separator/filter incorporates 99% efficient 3 micron elements. This ensure consistent water removal.

### 2.7.2 Airlift Control –

The air pressure regulator: has a balanced valve design. It has a spring-loaded diaphragm and 4 adjusting pressure ranges.

The oil coalescing air filter: is high-efficiency water removal, oil aerosols, and solid particulate contaminants down to .01 ppm/wt with minimum pressure drop. It is light weight and high flow capacity.

The pressure gauges: on this system are equipped with socket restrictor and glycerine filled case. Off-set case liquid filling port, LBM process connection and crimped tamper-proof bezel ring.

### 2.8 HUMAN MACHINE INTERFACE

The Programmable Logic Control (PLC) is located on each skid. This allows for efficiency and easy access. It controls the heaters and pumps. Variable frequency drives are also located on each skid to provide immediate adjustment of skid motors and components. Each skid is connected by a single Ethernet cable to the main control HMI.
2.8.1 Blending Tank –

Fully automated blending tank that follows a prescribed formula for each product. Additives are mixed according to precise weight in order to achieve required properties. This function allows the customer to produce high value petroleum products, such as transformer oil, when crude/base oil is at a low.

2.8.2 Hydrofoil Agitator –

Allows for mixing liquids together, promoting reactions within chemical substances and increases heat transfer for cooling and heating. These agitators improve pump flow, have low energy consumption and low magnitude and turbulence.
2.8.3 Agitator VFD and Controls –

Variable frequency drives and controls aid in maintaining and adjusting input/output speeds.

Figure 14 blending system component