FUEL OIL BURNERS

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INTRODUCTION

The history of burners dates back to the early shipping days, when fuel oil first started replacing coal as the ships’ primary fuel source.
Since then, burner designs and construction have come a long way, but the principles behind their operation has remained the same.
All makes and types of burners have two things in common:

- They need to atomise the fuel
- They need to mix the fuel with the air needed for combustion
Why do we want to use a burner?
To convert water into steam.
To heat thermal oil
For direct firing in cooking and oxidising
To provide heat to dry products
Why is it necessary to atomise fuel?

Even though fuel oil is classified as a flammable liquid, most fuels will not burn easily in a liquid state.

If you were to drop a lit match in a container of fuel oil, it would PROBABLY go out almost immediately (don’t try this!).

In order for fuel oil to burn, it must first be transformed from a liquid to a vaporised state ~ atomised. Atomisation increases the exposure of the fuel to the oxygen in the air; this promotes combustion.
A nozzle rated at 0.60 US gallons per hour can generate as many as 50 million droplets of oil in an hour.
EFFECTS OF BAD ATOMISING

If atomisation is incomplete, the droplet sizes are too large for complete combustion. The larger droplets will escape the flame only partially burnt. This can usually be seen as “fire flies” when looking at the flame. This will not only result in a poor flame, but also soot deposits being formed inside the combustion chamber. In addition the combustion plant’s efficiency will reduce causing excessive fuel usage for the required energy output.
There are generally four types of burners, each of which atomise fuel in different ways.

- Pressure Jet
- Air / Steam Atomised
- Rotary Cup
- Low Pressure Air Atomising
Pressure Jet Burner
The most common types of pressure jet burners in our industry are:

- Riello
- Weishaupt
- Nu-Way
- FBR
How a pressure jet atomises fuel

To create the ‘fuel vapour’, the fuel is pressurised, and forced through the nozzles.

This breaks the oil into mist-like droplets, that get mixed with the combustion air and ignited.

On heavy fuel oil, the fuel atomising pressure might be as high as 3000kpa (30 bar), for light fuel oils as low as 600kpa (6 bar).
Higher Fuel Pressure Lowers the Average Droplet Size
Selecting a Pressure Jet Burner

- Single stage – single nozzle - on / off ~ no modulation, no turndown ratio.
- Multiple stage (either 2 or 3 nozzles), the burner switches between the stages, increasing / decreasing the fuel throughput as required by the plant load.
- Spillback type nozzle – one nozzle with a variable throughput.
PRESSURE JET ADVANTAGES:

- Good atomisation
- Relatively low initial investment – low Capex
- Package type: “plug and play”
- Nozzles and spares are relatively inexpensive
- Maintenance is easily performed
- Reliable
PRESSURE JET DISADVANTAGES:

- Poor turndown ratio
- A small drop in atomising pressure or increase in fuel viscosity will increase the droplet sizes, causing a reduction of the combustion performance
- Limited range of fuels can be used
- Generally not suitable for very large appliances
AIR / STEAM-ATOMISED BURNER
HOW A STEAM-ATOMISED BURNER
ATOMISES FUEL

The fuel is supplied to the nozzle at a lower pressure than that of the conventional pressure jet burners (less than 600kPa ~ 6bar).
Steam or compressed air is also discharged into the nozzle.
These mix uniformly in the nozzle.
As this mixture leaves the nozzle, the expansion of the ‘gases’ produces a spray of finely atomised oil.
STEAM/AIR-ATOMISING NOZZLE

- Mixing Chamber
- Steam Holes
- Oil Holes
- Oil Holes
- Fine droplet spray
- Fine droplet spray
- Oil and steam mixing chamber
- Steam Holes
ADVANTAGES OF STEAM ATOMISING

- Steam atomising is tolerant to quality changes in the fuel; can successfully burn wide range of fuels
- These burners have better turndown ratios
- Does not require a high fuel oil pump pressure
- Lower pressures reduce nozzle and equipment wear
- Robust and simple
- Steam jacket can “cool” lance in hot furnaces
DISADVANTAGES OF STEAM ATOMISING

- Higher initial costs
- Can have ignition difficulties
- Suitable only for large installations
- Requires a source of steam, or a large amount of compressed air
- Nozzles are more expensive
ROTARY CUP BURNERS
HOW A ROTARY CUP BURNER ATOMISES FUEL

The fuel oil flows at low pressure (250kpa – 2.5bar max) onto the back of a spinning cup where it runs down the sides and is thrown off the cup rim as a very fine oil film.

The rotary cup is spun at high speed (about 5000 RPM) by an electric motor.

A primary air fan blows air concentrically around the outside of the cup, striking the oil film at high velocity and atomising it into tiny droplets.
ADVANTAGES OF A ROTARY CUP BURNER

- Good turndown ratio
- Robust
- Relatively unaffected by change in viscosity
- If it will burn, a rotary cup burner can handle it.
DISADVANTAGES OF A ROTARY CUP BURNER

- Expensive.
- Requires daily scheduled maintenance for reliable operation.
- Relatively complex to service
LOWPRESSURE AIR ATOMISING BURNERS
PRINCIPLE OF OPERATION

The oil is fed at very low pressure (20-50kPa) into a high velocity air stream. The high speed air “shears” the oil into droplets and air turbulence further mixes and atomises the fuel. The air source is generally a high pressure blower.
ADVANTAGES OF A LP AIR BURNER

• Very robust and can handle a large variety of fuels
• Relatively low initial cost
• Very good turndown
• Low running costs as no steam/compressed air is required
DISADVANTAGES OF A LP AIR BURNER

- Not the best atomisation available
- Generally suitable only for very hot or large furnaces such as billet reheating, smelters, rotary kilns, etc
BURNER FUEL REGULATION

The amount of fuel being burnt obviously needs to be regulated in order to maintain plant load as well as to facilitate proper fuel / air ratios.
NOZZLES AND NOZZLE SELECTION

- The smaller ‘fixed’ firing rate nozzles, such as the HAGO, or Monark range, all have ratings stamped on them.
- These ratings are always referenced to throughputs in USG per hour ~ at 700kpa (100PSI) oil pressure, on a light oil with a viscosity of 4cSt at 20 deg C.
- They also include the spray angle ~ we mostly use 60 deg nozzles, but in smaller diameter combustion chambers, a lower angle would be selected.
CALCULATING NOZZLE THROUGHPUT

For general purposes, change in flow rate due to changes in pressure can be estimated as being approximately equal to the square root of the pressure ratio.

Flow @ desired pressure

\[ \text{Flow @ desired pressure} = \text{Nozzle size} \times \sqrt{\frac{\text{Desired pressure}}{7}} \]
Example:
Calculate the throughput of a 12 USG nozzle at 25 bar

\[ 12 \times \sqrt{\frac{25}{7}} \]

= 22.7 USG or 86 Liters per hour
ROTARY CUPS

- Rotary cups don’t have nozzles to meter the fuel.
- The older type rotary cup burners would either control the amount of fuel being burnt with ‘volu-valves’ or with a ‘V-type’ regulator
  - Volu-valves have a series of holes that are opened or closed to vary the amount of fuel being delivered
  - V-type are simple yet effective v-groves that simply increase or decrease the open surface area, changing the amount of fuel that passes through.
- The newer designs use a positive displacement pump driven off a VSD, i.e. as the pump speed changes, so does the fuel delivery.
HEATER PACK

As burners have different methods of atomising their fuel, so their fuel viscosity requirements also differ. Most fuel oils are not viscous at ambient temperatures, so it is necessary to heat them up to require the correct atomising viscosity. Unfortunately this is a weak point, as most burner technicians stick to traditional atomising temperatures and pay no attention to the required viscosity for the burner in relation to the supplied fuels.
FO150 VISCOSITY

FO150 Viscosity Graph

FO150 Viscosity Graph

Temperature (degC)

Viscosity cSt
VISCOSITY REQUIREMENTS

• Rotary Cup Burners
  • Can handle down to 3.5 centiStoke and as much as 70 centiStoke

• Pressure Jet
  • Up to 17 centiStoke (only on the larger nozzles)
TYPES OF IGNITION

There are two ways that burners ignite fuel oil (apart from delayed ignition igniting from hot refractory)

- Electric Spark
- Gas
SPARK IGNITION

Spark ignition consists of a high voltage transformer, usually between 6000VAC and 11000VAC. The spark is emitted through a set of electrodes, which ignites the atomising fuel oil. Positioning the electrodes is a precise task. If the electrodes are set too close to the nozzle tip, the spark may jump to the nozzle, causing poor ignition. The same can be said if the electrode is in the oil path - the spray will smother the spark, also causing poor ignition.
GAS IGNITION

A gas flame, known as a pilot light, is directed straight on to the atomising fuel oil causing it to ignite.

Gas ignition is more reliable than spark ignition and is generally used in larger burners.
FLAME DETECTION

It is important to monitor the flame on all burners. If the flame fails or goes out, the oil supply to the burner must be shut down. Flame monitoring is done by either using

- A photoelectric cell or
- Ionisation probe.
P.E. Cell

Photoelectric cells can be divided into two categories. One type detects visible light and the other U.V. light. The lower-cost burners will employ the conventional light detector, whereas the higher-range burners will use the superior U.V. cells.
IONISATION PROBE

The ionisation probe consists of a rod insulated by ceramic, which is immersed into the flame space. Under flame conditions, the potential difference between the probe and the earth body increases and the probe, being immersed in the flame, becomes ionised allowing current to flow from the probe to the body. This current is measured and if it drops off, the flame has gone out.

This type of flame detection is only used on pilot gas ignition and on gas-fired burners.
INTERLOCKS

- All burners have (should have) safety interlocks fitted. When they become unsafe the plant shuts down. There is a tendency in industry to bypass troublesome interlocks rather than to repair them, which renders the burner unsafe. Some operators even remove the flame detectors and place them in direct sunlight when they are experiencing unstable flames.
TYPES OF INTERLOCKS

- Burner door switch
- Low fan pressure
- Low ring main pressure
- Flame detection
- Pilot light detection
- Low fire oil position
TYPICAL LIGHT-UP CYCLE.

- Fan on.
- Dampers drive to high fire position.
- Pre-purge (±45 sec).
- Dampers close to light up position.
- Spark / pilot ignition (±5 sec).
- Oil solenoid opens.
- Flame ignition detection.