INFORMATION SHEET 2 – THE TROUBLE WITH VRF / VRV

Variable **R**efrigerant **F**low air conditioning systems.

Variable **R**efrigerant **V**olume air conditioning systems.

Jackson Engineering Advisers are specialist Building Services Engineers.

This information sheet is offered as an aid to Building Owners and Managers as a guide to getting the best out of your VRF systems. We trust you will find it of value.

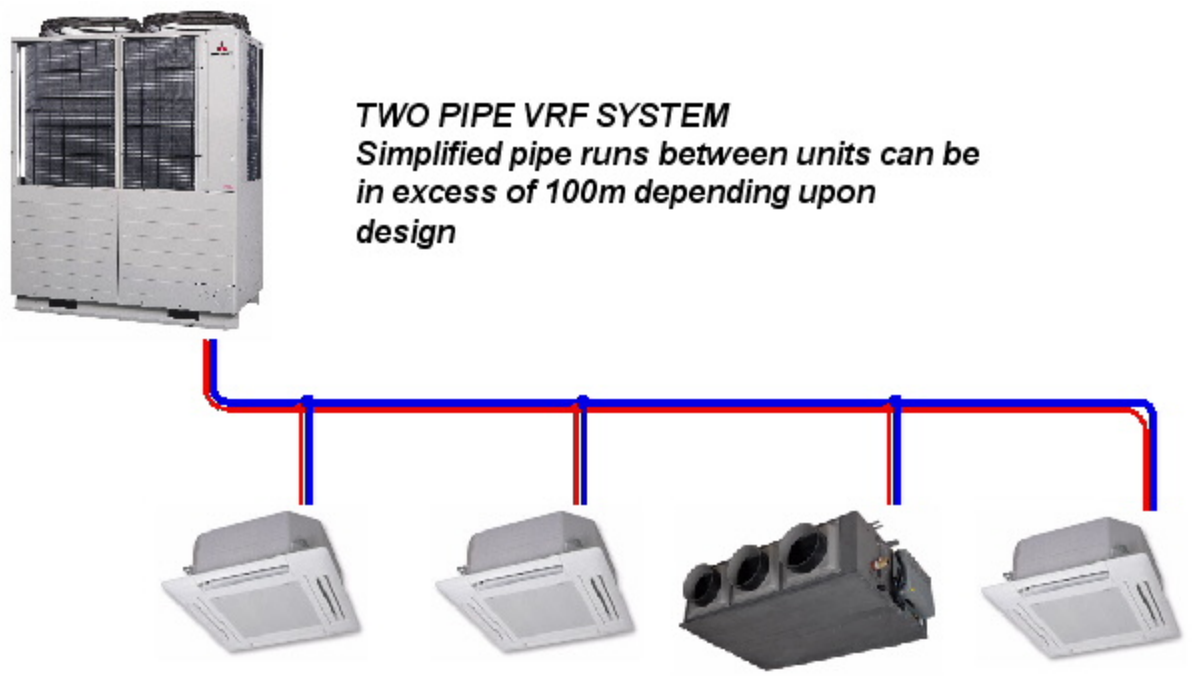
Please contact us if you require assistance with:

- Air Conditioning System Diagnostics and recovery of troublesome VRF systems.
- Building Services Plant Operational Audit.
- Continuous Commissioning programmes – (Building Performance Management).

WHAT IS A VARIABLE REFRIGERANT FLOW SYSTEM?

VRF uses refrigerant as the cooling / heating medium, and allows one outdoor (condensing) unit to be connected to multiple indoor (evaporator) units.

Each indoor unit is individually controllable by its user and a variety of unit styles can be mixed & matched to suit individual tenancy requirements.



By operating the refrigeration compressor within the outdoor unit at varying speeds, VRF units work at only the rate needed to meet the prevailing heating or cooling requirements. Their efficiency is further enhanced by models with the ability to provide simultaneous heating and cooling.

An example of this occurring is when cooling is required to east facing offices subject to direct sunlight on a cool sunny morning. The heat extracted from these offices can be delivered via the VRF system to units on the south or west faces where heating is required.

System Uptake

VRF systems have been around for almost three decades, but they are relatively new to New Zealand, having arrived here in the late 1990's. As design engineers become familiar with the technology and the drive for energy efficiency increases, more people in the industry seem to be willing to give the systems a try.

Reports indicate that approximately half of new medium sized commercial buildings in Japan (up to 6,500m^2) are now serviced by VRF systems.

Uptake in NZ has been slower, but has been gaining momentum steadily over the last 5 - 8 years. The system is now a common choice of designers for small to medium size office buildings.

Energy Efficiency

If you search the web or talk to suppliers, some pretty impressive (and rather optimistic) energy savings figures are being quoted. Such figures are normally quoted as 'percentage' savings, as opposed to absolute energy usage and there is generally no reference as to what the savings are being compared to.

Our experience, coupled with computer aided building thermal analysis is that 'modest' energy savings can be made, depending on geographical location as well as many other individual site factors. A few pertinent points in assessing comparative performance are:

No 'free cooling' ability

Unlike central plant systems such as VAV (Variable Air Volume), VRF systems cannot provide 'free cooling' by utilising cool outside air. In many parts of New Zealand and in particular the North Island's relatively temperate climate, the ability to utilise outside air for cooling whenever the outside air temperature is lower than the building exhaust air temperature, is a source of significant energy savings.

Heating

VRF systems, like most other reverse cycle air conditioning systems, provides efficient heating, with typical efficiencies of around 300%, compared to 100% for straight electric heating. However, in the temperate North Island climate, heating is probably only going to make up about 10% of your energy usage, with the rest of the energy needed to remove excessive heat from the building. i.e. the systems spend 90% of their time in cooling operation. Realistic savings from the heating cycle are therefore about 2/3^{rds} of 10% or 6.6%.

Mechanical cooling

In straight cooling operation, VRF systems offer broadly similar efficiencies as any other conventional refrigerant based system, such as chilled water or split systems. Of note, the relatively new Turbocor (oil-less compressor) chillers will outperform VRF in cooling operation by a considerable margin, but capital costs are still relatively high.

Simultaneous heating and cooling

The VRF systems ability to extract heat out of zones requiring cooling and make it available to zones requiring heating is where VRF systems perform very well. But….

While this is a great feature and the efficiency numbers are impressive, the times that this feature is actually required for many buildings makes the benefit small.

An example of a typical medium sized commercial office building in Newmarket, Auckland that we recently modelled, found that the requirement for simultaneous heating and cooling was only about 10% of the time that the system spent in heating mode, which was also circa 10%. In other words, we achieved very high efficiencies for about 1% of the time.

The benefits of this feature improve as the climate tends to the extremes, so the energy savings are better for the South Island and better again for Europe or North America, where much of the published data emanates from.

The moral of the story here is to look at the facts, not the capabilities of the system that may only be applicable for a small amount of time.

CONTROL SYSTEMS

VRF offers a high level of individual user control, with features that can be enabled or disabled to suit particular applications. The internal unit controls are very complex and specialist training for service engineers is required to diagnose and correct problems.

System Problems

As a company that specialises in the built environment, offering trouble shooting and diagnostic services for 'problem' air conditioning systems, we see our fair share of issues with the many different and bespoke air conditioning systems installed.

A disturbing trait is emerging where VRF systems show signs of trouble, in that when things go wrong, they tend to go from bad to worse over relatively short timeframes and can render complete systems unusable well before expectations.

We have been involved in the diagnostics and replacement of several VRF systems that have by all accounts been troublesome and have ultimately failed prematurely – some within 7-8 years of their original installation date.

Given that these systems are relatively expensive and the cost and disruption associated with early replacement is very high, it is little wonder that some building owners are questioning the future of these systems for their buildings in New Zealand – despite apparent global trends of increasing sales of these products.

So what's going wrong?

There are several areas we see as possible contributors to early failure:

1. Obsolescence
2. Poor installation
3. Poor maintenance
4. Poorly executed system alterations (e.g. fit-out alterations)
5. Choice of refrigerant
6. The right people

Obsolescence

Over the past 10 years, VRF technology has developed rapidly, particularly with respect to control systems riding on the back of IT developments, and the adoption of new ozone friendly refrigerants.

Some of the earlier VRF systems introduced to NZ about 10 years ago are now effectively obsolete, with parts being increasingly expensive and difficult to source. These earlier systems were invariable based on R22 refrigerant, which is following its own path to obsolescence via established legislation.

Where parts are unavailable or expensive and the system is reliant on R22 refrigerant, the point of no return is quickly reached, leaving the only viable option for the building owner to replace the system.

Poor Installation

The spidery nature of VRF pipework and specific installation requirements which vary by manufacturer makes the standard of the initial installation a crucial factor in the life expectancy of a VRF system.

At the end of the day, these are complex refrigeration systems that should attract at least the same level of care and attention to detail as afforded to large chiller or industrial refrigeration systems.

Refrigerant leaks, improper evacuation, poor or no pressure testing and the lack of nitrogen purging during pipework welding can all result in premature failure of the systems, despite the fact that these issues will usually see the system through its construction warranty & guarantee period.

If your installation looks like that below, it is hard to imagine much care has been taken with system commissioning or that the required attention to detail has been provided to avoid future problems.

Insert Photo

Photo of a recent installation under investigation

Insert Photo

Photo of a recent installation under our guidance.

Poor maintenance

VRF systems are one of the most difficult systems in which to detect and locate refrigerant leaks. Some of the contributing factors are:

- The size of the systems – it can take weeks or months for a slow leak to become apparent from the systems performance.
- Where refrigerant pipes are run in inaccessible or difficult to access spaces, physical leak detection is difficult.
- The high number of field joints compared with chillers or split system type installations increases the risk of leaks.
- It is very difficult to determine if refrigerant levels are correct by simply connecting refrigerant pressure gauges, due to the widely varying operational states that can exist as the indoor units all behave independently.

Where a loss of refrigerant has been detected, the only sure way to re-charge the system with the correct volume of refrigerant is to decant all of the refrigerant out of the system and replace it with a known (weighed) quantity.

Time and cost pressures often mitigate against this practice.

Poorly executed system alterations

Typically resulting from fit-out requirements part way through the equipment's normal life cycle, system alterations must be done under the same strict standards as if it was a new installation.

Often shut-off / isolating valves to aid shutting down individual indoor units have not been installed as part of the original installation, and without such devices, the whole system must be shut down to cater for relocation of a single indoor unit. This adds time and cost pressures to the contractors to get the job done quickly to minimise disruption to other tenants. Proper commissioning procedures are often cut short.

Choice of Refrigerant

Older systems will be based on R22 refrigerant, which as most people are now aware, is subject to a ban on new imports from 2015. While service stocks will continue to be available, the price is expected to rise as demand for available stocks increases.

Systems based on the use of R407 were introduced from about 2004 for a few years until R410a became the new default refrigerant for these systems.

R407 is a unique blended refrigerant consisting of two main components with different temperature / pressure characteristics. The significance of this is twofold:

- System operation by observing pressure / temperature relationships as per standard refrigeration practice becomes almost impossible.
- Should a leak occur, one of the components will leak more than the other, meaning that a simple 'top-up' of the leaked refrigerant is less viable, as the consistency of the refrigerant will be altered. Full system decanting is required, adding to both cost and the time required for the remedial work.

The right people

An observation, although potentially contentious, is the level of skill offered by many installation companies providing and maintaining VRF systems.

At the residential end of the market, relatively inexperienced and perhaps lesser qualified trades staff are installing split system air conditioning units with a great deal of success. At the opposite end of the spectrum, industrial refrigeration engineers tend to work on large chillers and complex industrial sites utilising various refrigerants, including HCFC's (as found in VRF systems), ammonia, carbon dioxide and hydrocarbons.

The anomaly lies in that VRF systems are complex and could be considered relatively fragile, requiring very high standards of design, installation and maintenance.

Despite these characteristics, many installers come from the lesser experience and lesser qualified end of the market. VRF, and in general commercial air conditioning applications, are failing to attract the high calibre of staff needed to get the best from these systems.

While it is true that industrial refrigeration engineers may be more expensive than typical service providers, these costs fade into insignificance compared with the costs attached to premature system failure.

When the wheels fall off

Compressor failures occur in many systems, ranging from complex chillers to simple split system air conditioning units for a variety of reasons. Repairs are generally undertaken if economically viable and provided the diagnosis is thorough, root causes are identified and proper remedial work is undertaken, are for the most part successful and the systems resume normal operation.

However, we have observed several VRF systems to experience on-going problems, seeming to go from bad to worse. So what's different about VRF?

Well several things actually. Our observations are as follows:

- Many faults experienced with VRF systems render the complete system failed. Typical systems can serve between 4 to 16 indoor units, so a small fault on one unit can affect anything up to 100 people. This adds severe pressure to the service provider to get the problem fixed and get the system operational as soon as he can.
- Oil that has become acidic causing an electrical compressor failure must be removed from the system. Often residual oil is difficult to remove unless suction accumulators are removed and replaced as well as the failed compressor. This is rarely done, so the new compressor starts out life in an acidic environment, leading to another premature failure. If repetition of this process is allowed to occur, a runaway trail of compressor failures is likely to result leading to overall system failure.
- Mechanical damage due to lack of oil (or foaming oil due to low refrigerant levels) will result in metal 'fines' being released, as metallic components wear excessively. These 'fines' can block refrigerant strainers, which are generally non serviceable and inaccessible. This causes a further lack of oil return to the compressor & ultimately compressor mechanical failure. As above if this process is allowed to repeat, a runaway trail of compressor failures is likely to result.

Types of failure

How do serious problems manifest from the above issues? To avoid the slippery slopes of repeat compressor failures, there are a few rules which cannot be broken.

The complex nature of VRF systems can result in many different problems. As for any complex electronic equipment, electrical, electronic and control component failures can and do occur. Controls component failures can be exacerbated by vibration from fans & compressors, exposure to excessive temperatures and poor quality power supplies.

However, the most common 'serious' problem for a VRF system is a compressor failure. Compressor failures are generally classified as electrical - compressor motor failure, or a mechanical compressor failure. Assessment of the systems oil will provide one of the biggest clues as to the root cause of the failure.

The most common cause of an electrical (or compressor motor) failure is from the systems oil becoming acidic. (The oil can become acidic due to undiagnosed leaks, poor installation / workmanship & previous compressor failures). The acidic oil eats away the electrical insulation on the motor and causes an electrical 'short'. The service report is likely to say that the compressor motor is 'down to earth' or has an 'earth fault'.

The most common cause of a mechanical (compressor) failure is a lack of oil, usually caused by sludge and blocked strainers and oil-ways within the machine. Mechanical damage to the compressor and suction / discharge valves usually results. The service report is likely to say 'compressor failure'. Mechanical or valve damage can only be confirmed if a compressor is cut-open for diagnosis.

A compressor replacement is required under either mode of failure.

System Installation

It is critical that the standard of installation is as high as possible. All welded joints must use nitrogen purging to stop impurities entering the system, service valves should be installed to allow disconnection of individual indoor units and both pressure testing and proper evacuation procedures should be undertaken, witnessed and signed off.

Pressure testing is often omitted due to time pressures, but is required. Pressure testing pipework and joints stresses the metals in different directions than achieved by evacuation procedures. Leaks that show up under a pressure test may not show up under an evacuation test.

Proper triple evacuation is required and will ideally be done by measuring the level of vacuum rather than by time alone. Sufficient time must be taken, particularly in cold weather to allow all of the moisture to be drawn out of a system. There is no short-cut for this process. It will take as long as it takes and on a large system, it could sit under vacuum for 3-5 days.

Often time pressures at the end of the construction period will make these tasks difficult to achieve to the level required.

By comparison, chillers arrive to site having been properly evacuated and charged during manufacture before leaving the factory. Simpler split system installations have much smaller refrigeration systems, so do not require the same time for evacuations as large VRF systems.

System maintenance and remedial work

If repairs, such as a compressor or other refrigeration component replacement is required or remedial work such as relocation of an indoor unit is required; all of the measures relating to a new installation will be required – there are no shortcuts without consequences.

One significant difference from new build installations is that there is likely to be significantly more pressure to get the system back up and running due to the building occupants complaining of no air conditioning.

The temptation is to take shortcuts – don’t decant all of the refrigerant & weigh it back in, don’t bother about doing pressure tests and do a quick triple evacuation before putting the system back into service.

The results we’re seeing from this type of service & remedial work suggest that within 1-2 years, you are likely to experience a further compressor failure on that system, followed by more failures at decreasing intervals. We have seen projects where new compressors last about 9 months.

System Recovery

So the question that needs to be raised is that if you experience a compressor failure, can you do anything differently to avoid a series of repeat failures?

The answer depends on how far your system has progressed down the path towards the point of no return. Generally speaking, one or two compressor failures should be recoverable, but for every failure, your chances of recovery get slimmer.

However, the road to recovery requires a considerable effort and a planned attack by a competent service provider is required.

Depending on the mode of failure and the history of failures to date, it might be necessary to remove the refrigerant, change the liquid receivers, pressure test and re-evacuate the system – requiring the system to be off-line for about 4 days. While the system is down, appropriate valves need to be installed for future isolation and to allow regular oil samples to be taken without interfering with the system.

Burn-out driers with isolation valves will be required and plan on changing them with monotonous regularity for the first few months to a year.

On-going monitoring of the oil will be required and if the oil shows any signs of increased acidity, the refrigerant and oil will need to be removed and replaced.

This is all going to cost a lot of money, but the alternative of business as usual will ultimately end in overall premature failure of the system.

LIFE EXPECTANCY

So how long should a well maintained VRF system last?

In our June Information Sheet on plant life expectancies, VRF was rated at 10 years, based on extensive UK data. As we have stated in the past, much of NZ should be considered coastal which will shorten the life of the outdoor units in particular. It is our opinion that outdoor units must be supplied with factory applied corrosion protection for use in almost any NZ location. The small additional cost simply makes good sense and will increase the operational life of the unit.

The critical factors towards getting most out of your VRF system are:

- The equipment must be installed to the highest of standards
- Proper pressure testing of all pipework must be completed and witnessed
- A thorough triple evacuation scheme is required, allowing sufficient time for all moisture to be removed.
- The refrigerant charge should be weighed in.
- Any invasive refrigeration work throughout the life of the equipment must be completed by a well-qualified refrigeration engineer following good industrial refrigeration practices.
- If a refrigerant leaks occurs, it must be properly repaired, the refrigerant removed and new refrigerant weighed in.
- Sufficient time must be afforded to the service engineers to allow proper evacuation of the systems before being put back into service.
- If a compressor failure occurs, proper diagnostics are required and a proper recovery plan should be implemented.

If the above guidelines are followed, we remain optimistic that a life expectancy in excess of 12 years could be achieved.