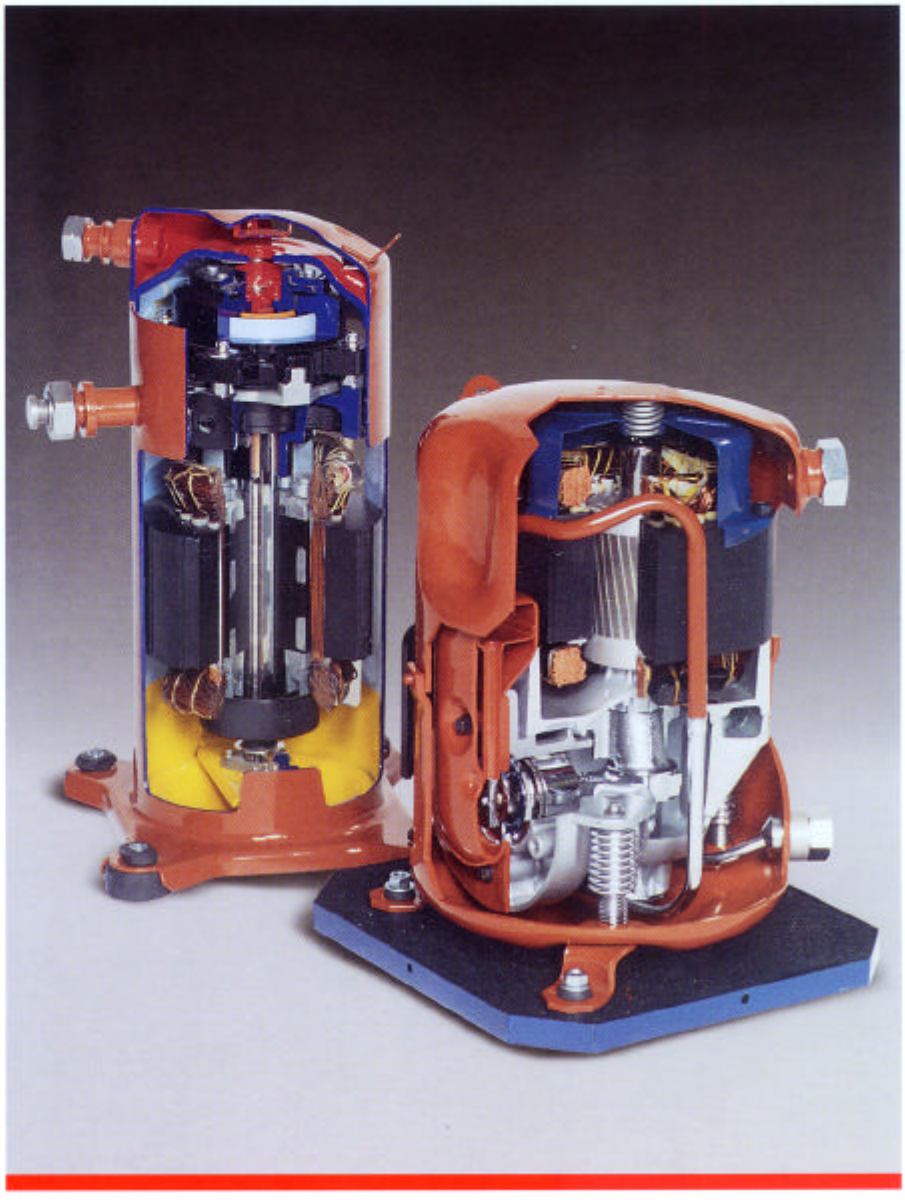
TRANE®

Special Report

An Engineering Report On Climatuff® Compressor Technology



Climatuff® Compressor Technology

Index

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Section I – Introduction To Climatuff® Compressors

Special Report Introduction And Background

Trane, a world-leading HVAC company, now manufactures 4 of the 5 leading compressor technologies. Centrifugal and screw compressors from 35 to 1300 tons are manufactured by the Worldwide Applied Systems Group. Reciprocating and scroll compressors from 1 to 15 tons are manufactured by the Unitary Products Group and the Worldwide Applied Systems Group.

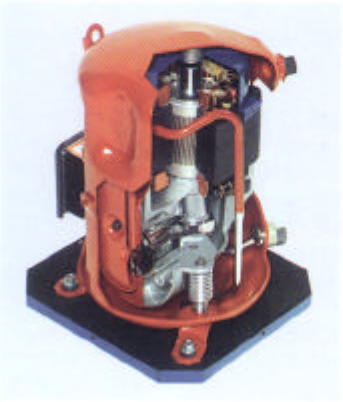
Trane Is A Pioneer In The Four Compressor Technologies.

- In 1938, the industry's first hermetic centrifugal refrigeration machine was introduced by Trane. The Turbovac is the forerunner to today's CenTraVac, Trane's highly successful refrigeration unit and the industry standard for large commercial air conditioning systems.
- In 1987, Trane introduced a new generation water chiller which featured the most advanced large tonnage compression technology – a helical rotor or screw compressor. Trane's screw compressor with 5 and 7 lobe rotor combinations resulted in the highest screw compressor efficiencies in the industry.

- Reciprocating compressor technology has a dual heritage. For the commercial sizes, Trane began manufacturing its own compressors in 1950. For residential compressors, the heritage goes back to the 1930's to the first hermetic compressor. This provided the technology basis for the world's first reliable heat pump compressor, the Climatuff® which debuted in 1964. Both compressors have repeatedly undergone several redesigns maintaining their pre-eminent reputation in the industry. Trane reciprocating compressors have established several industry "firsts:" the first hermetic 30 ton compressor, the first reliable heat pump compressor, and the first successful 3 and 5 ton variable speed compressor. These are some examples of Trane's commitment to compressor innovation.
- Scroll compressor technology is the latest area where Trane has made significant contributions. After 14 years of research and testing, Trane introduced the 3-D® scroll compressor in 1988, the industry's first scroll designed specifically for the commercial air conditioning market.
- And in 1998, after proving scroll technology in the demanding commerical market, Trane now introduces the Climatuff® residential scroll compressor. This scroll compressor follows in the Climatuff® reciprocating compressor tradition utilizing similar design and testing philosophies to provide maximum reliability and durability, industry leading efficiency, and low noise levels.

Compressor technology is an integral factor in Trane's success. Trane understands compressor technologies; Trane advances compressor technologies; and Trane introduces compressor technologies into the products when the time is right.

Section II – Reciprocating Technology



Reciprocating Introduction

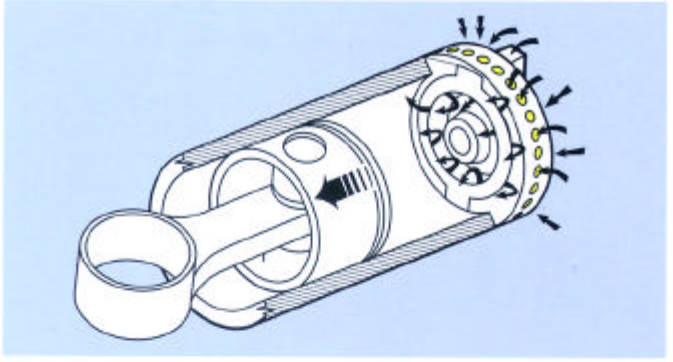
Trane's Climatuff® reciprocating compressor was the world's first successful heat pump compressor. From its inception, the Climatuff® philosophy revolved around two fundamental principles.

1. The compressor must be able to protect itself in all systems with minimum reliance on system controls.

2. Compressor reliability and durability is to be proven in the laboratory not at the customer's site.

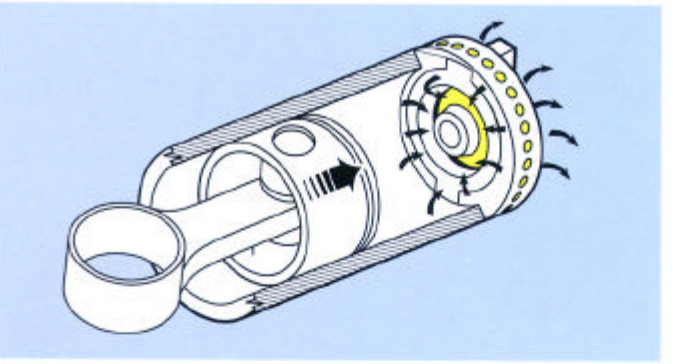
These two philosophies have been continually improved and today's Climatuff® reciprocating compressor remains a world leader.

How Reciprocating Compression Works:



These two diagrams illustrate the importance of valve design to gas flow efficiency and liquid refrigerant tolerance.

On the downstroke, when pressure in the cylinder is less than suction pressure, the suction valve is pushed off its seat allowing refrigerant into the cylinder. The gas enters efficiently in a cylindrical pattern around the circumference of the valve.



On the upstroke, the suction valve closes preventing refrigerant from leaving the cylinder. When cylinder pressure exceeds discharge pressure, the large round discharge valve lifts completely off its seat allowing gas to efficiently exit the cylinder. If there is liquid present, flow dynamics resulting from tapered surfaces and valve proximity will allow the liquid to be purged from the cylinder without damaging the valves. Besides being gas flow efficient, Climatuff®'s valving is engineered to tolerate some liquid slugging.

Valve design is critical to liquid refrigerant tolerance. On mild days, liquid refrigerant can accumulate in the suction line and will flood into the compressor on start-up. Because of this, the valves must be able to tolerate some slugging. Climatuff®'s valve assembly has been designed to allow liquid refrigerant to be expelled from the cylinder without damaging the valves.

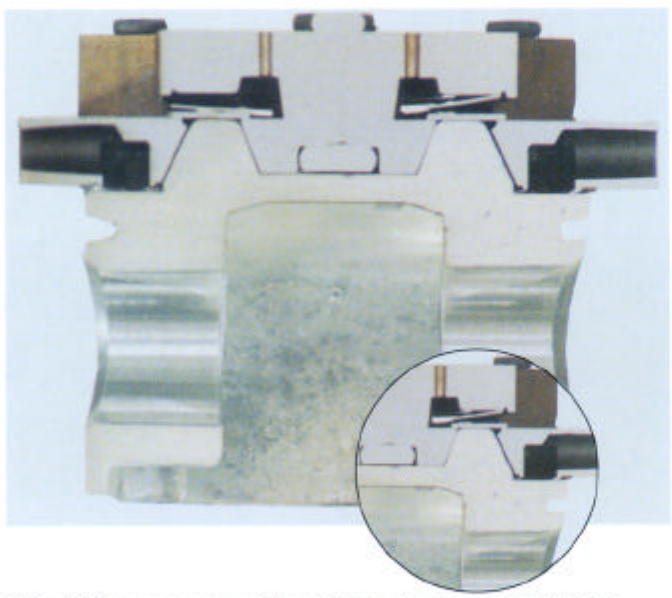
All Climatuff® reciprocating compressors have the **discharge line routed through the compressor sump**. With the compressor running, the hot discharge line will vaporize liquid refrigerant in the sump separating it from the oil. In the off cycle, Trane uses crankcase heat on all compressors (except low efficiency cooling units where refrigerant quantity is small) to vaporize liquid refrigerant and maintain desired oil temperature.

Climatuff® reciprocating compressors have an average of 25 percent more volume inside the shell than other compressors. This gives it additional safety margin against slugging which can be caused by overcharging or low indoor airflow. **With a large shell design, Climatuff® compressors eliminate the need for suction line accumulators on residential systems.**

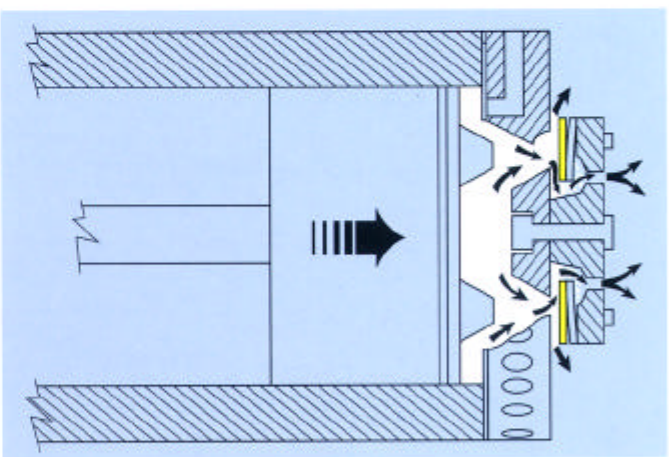
Section II – Reciprocating Technology

The Climatuff® compressor's lightweight piston and connecting rod allow for easy starts and higher running efficiencies. A pearlitic cast iron cylinder liner is used for durability.

The Climatuff® compressor's piston features a specially designed sculptured head that provides minimum clearance volume in the cylinder on the full upstroke of the piston. Low clearance volume yields higher volumetric efficiency. The sculptured piston head also eases liquid refrigerant stresses in extreme conditions.

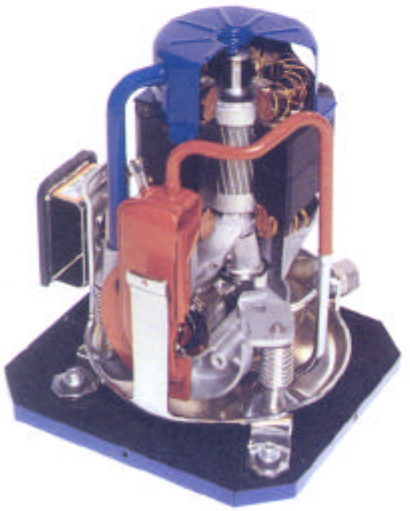


Climatuff® compressors: The piston and valve assembly have been mounted in plastic and cut in half to show the clearance volume. ***The clearance between the piston and valve assembly in the full upstroke position is just a few thousandths of an inch.*** *This leads to high volumetric efficiencies and high EER ratings.*



The Climatuff® compressor's discharge valve system consists of a floating ring valve and a computer designed valve spring. On the upstroke of the piston, the discharge valve will completely lift off its seat giving equal discharge clearance around the circumference of the valve. After this, the valve spring closes the discharge valve uniformly on its seat.

Section II – Reciprocating Technology



How Acousti-Cool Works

Refrigerant is returned to the compressor through the high level suction inlet. As gas is drawn into the compressor, it is approximately 100 degrees cooler than the motor windings. The gas enters the motor/cap and flows across the top of the motor. The gas continues through the top of the suction tube and enters the cylinder with no more superheating.

When the suction valve closes, the incoming flow of gas is stopped until the next intake stroke. This abrupt stop creates a pressure pulse that travels backward along the inlet path at the speed of sound. The pulse of refrigerant vapor hits the top of the motor, muffling noise as it cools the windings.

The lower super-heat means higher compressor efficiencies (EER). While being cooled, the motor/cap are performing the duty of a suction gas muffler. Since potential sound energy is being absorbed simultaneously with return gas motor cooling, the process is called Acousti-Cool.

Acousti-Cool is engineered motor temperature management. Managed motor cooling allows the compressor to run cooler than other hermetic compressors. Motor cooling leads to longer motor life and lower operating costs.

Crankcase Pressure Recovery

The Climatuff® reciprocating compressor utilizes an enclosed crankcase. Enclosing the crankcase protects the critical conrod/crankshaft journal bearings by limiting the amount of liquid refrigerant and particulate in the bearing area. The oil sump is separated from the spinning crankshaft providing an undisturbed oil supply.

During the downstroke (expansion) pressure in the crankcase is increased providing a small amount of refrigerant for injecting into the oil. This produces a small layer of oil foam that minimizes sound transmission. Crankcase pressure developed during the downstroke is recovered in the upstroke (compression) contributing to high efficiencies.

Section II – Reciprocating Technology

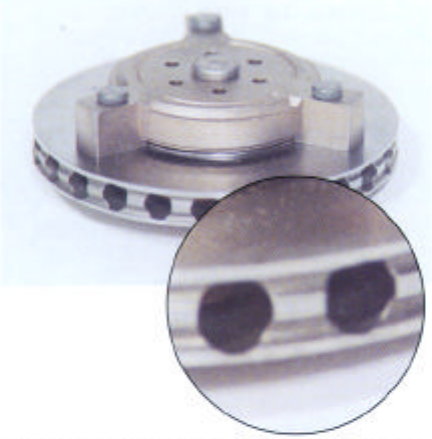
An all-aluminum frame, motor housing, piston and connecting rod help to reduce thermal stress and help the compressor to run cooler by dissipating heat away from the bearing surfaces.

Compressor Stress Capability

The Climatuff® compressor utilizes **aluminum pistons and connecting rods**. The lightweight aluminum provides for easy starts and relieves stress on the crankshaft. Trane uses an **industry-unique pearlitic cast-iron cylinder liner** for durability. For superior sealing at all heat pump operating ranges, Trane uses a cast-iron compression ring.

The Climatuff® compressor's **all-aluminum frame and motor housing** dissipates heat away from bearing surfaces. This reduces thermal stress and allows the compressor to run cooler than cast-iron frame compressors. The frame's light weight reduces stress on the mounting springs. The frame is designed with a very large intake area to minimize the dynamic pressure drop of suction gas. Suction gas flow to the valve is virtually unrestricted.

The Climatuff® compressor's discharge valve intake side, shown above.



The Climatuff® compressor's rugged valve assembly is the most critical component of the compressor. Discharge side shown above with an exploded view of the 24 intake ports.

Mechanical Stresses

Under certain operating conditions, there will be some liquid refrigerant flooding back to the compressor. This can lead to liquid slugging. While no reciprocating compressor is designed to pump liquid refrigerant, Climatuff® has superior tolerance to slugging.

The valve is the most critical component of the compressor. It experiences more mechanical, thermal, and pressure stresses than any other component of the compressor. Trane manufactures all their valves to extremely tight design specifications. Valves spring open and shut 57 times a second, up to 800 million times a year on heat pumps. Since Climatuff® compressors are designed for heat pump applications, a valve material that is practically indestructible is required.

The discharge valve and suction valve are made of special Swedish-type valve steel. The steel has a unique microstructure that has a high carbon content and a very low content of nonmetallic inclusions such as sulfides and silicates. This makes the valve highly impact and distortion resistant. The valve is resistant to metal fatigue and is not affected by excessive heat.

The Climatuff® compressor's valves are made of Swedish-type steel to handle extreme heat and the stress of opening and closing 57 times a second.

Section II – Reciprocating Technology

Large shell design with magnet to attract and hold metal chips from entering reciprocating system.

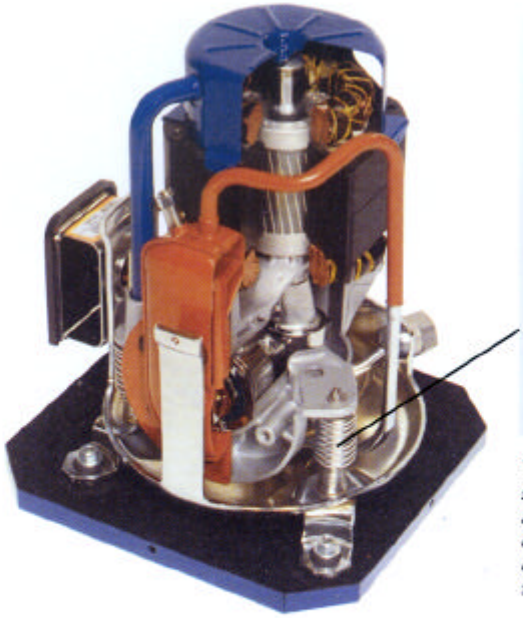
There are some distinct advantages to the Large Shell Design since it acts as the accumulator thus minimizing the potential oil traps, system leaks, and pressure drop of a separate accumulator.

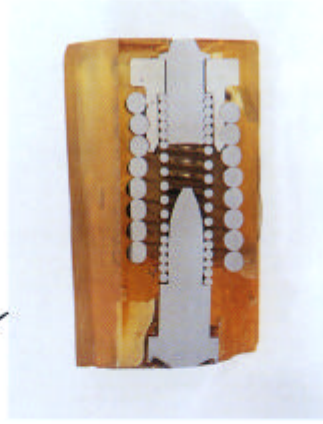
Good lubrication is essential to long compressor bearing life, and is one of the keys to the Climatuff® compressor's reliability. The Climatuff® compressor's crankshaft doubles as a positive, non-directional, centrifugal oil pump. It provides a constant oil supply to the bearing surfaces when the pump is running. In addition, it helps vaporize liquid refrigerant and cools the motor and bearings.

On system start-up, oil may have drained or been washed off bearing surfaces by refrigerant migration. If the system is overcharged, the oil reservoir at the bottom of the sump could be floated above the oil pump opening by the heavier liquid refrigerant. All of this can result in dry bearings that can seize a compressor on start-up. To counter this, Trane tin plates its bearings to serve as a boundary lubricant until oil flow is established.

Tin plating can be seen on the connecting rods. Since tin melts at 449° F and aluminum considerably higher, the tin will soften and lubricate the bearing until oil is supplied to the bearing surface.

Another mechanical stress is absorption of inertia energy during starting and stopping. Climatuff® compressors utilize a patented dual spring mounting system to absorb this energy. Heavy snubber springs quietly isolate the running compressor inside the shell. Stress is reduced on external connections because of minimized shell vibration. The result is long system life.





Trane has a patented dual spring mounting system that absorbs starting and stopping energy. This reduces stress on external connections and leads to long system life.

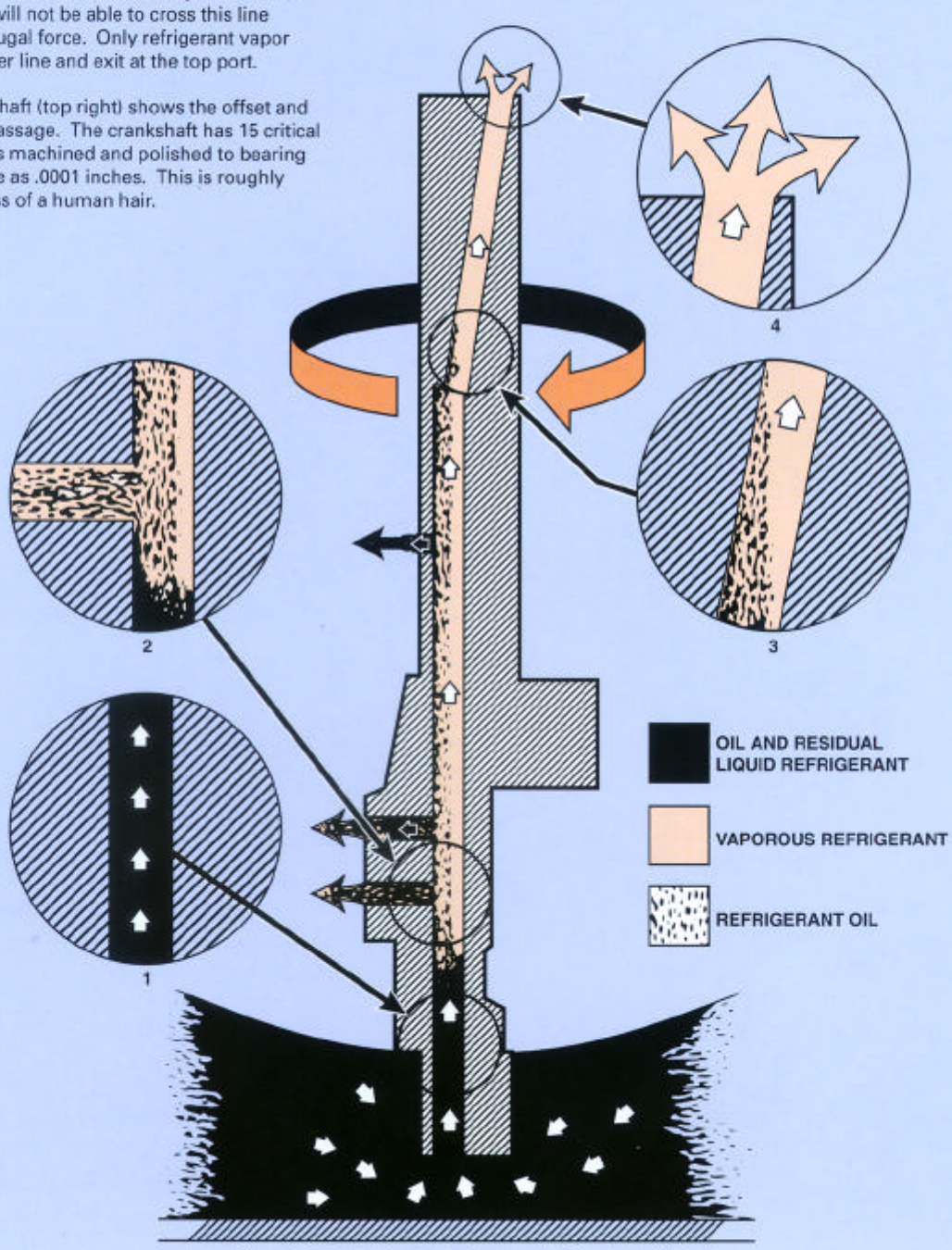
The Climatuff® Compressor's Crankshaft/Centrifugal Oil Pump... Engineering Technology from Top to Bottom

1. The oil passage slot in the bottom of the crankshaft picks up the oil and residual liquid refrigerant from the compressor sump. This mixture is lifted by centrifugal force up the oil passage.

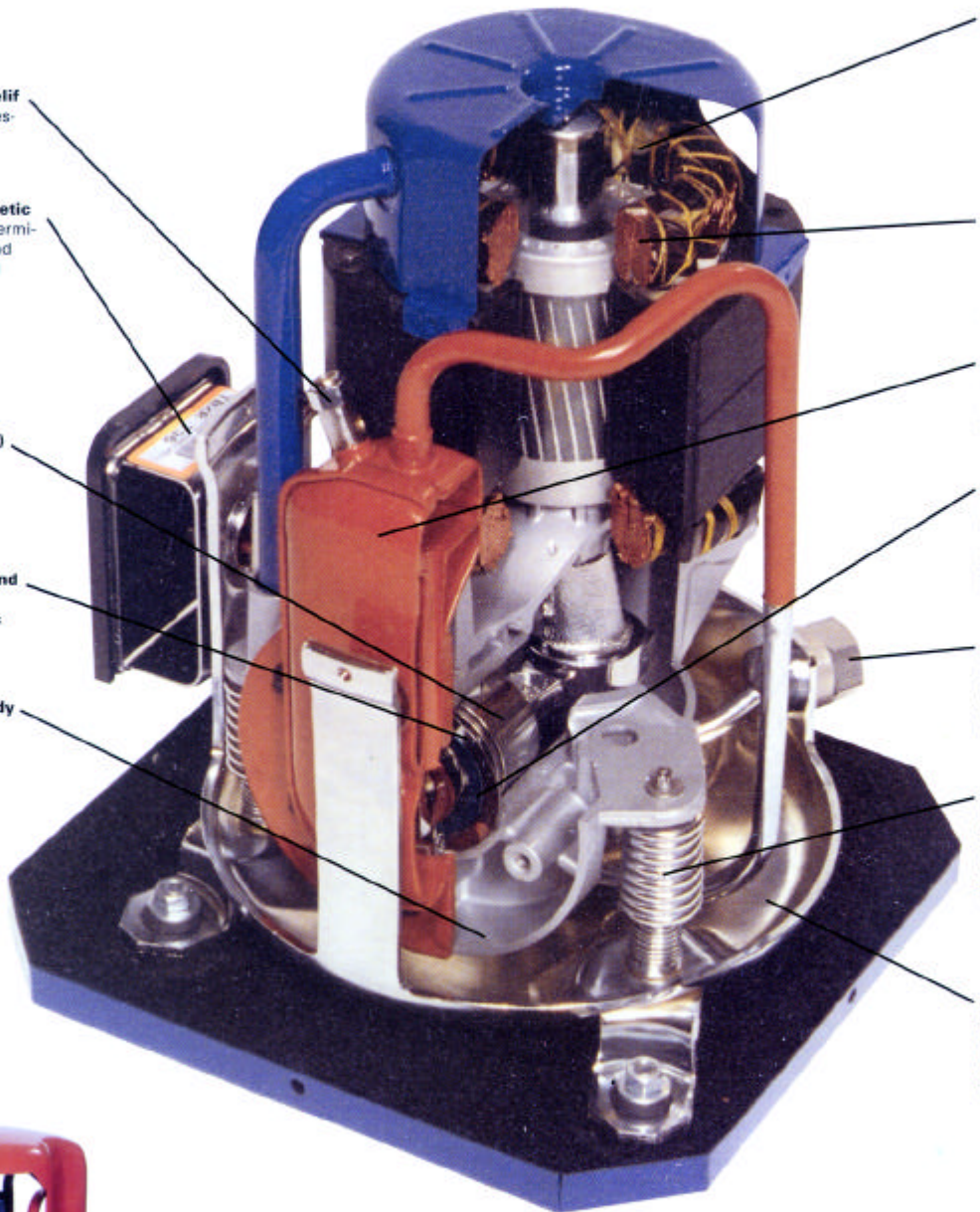
2. The hot surface of the crankshaft begins to vaporize the liquid refrigerant that has been picked up with the oil. Centrifugal force caused by the rotating crankshaft begins to separate the oil from the refrigerant vapor. The heavier oil is slung to the outside of the oil passage where it will be delivered to bearing surfaces through ports in the crankshaft. Refrigerant vapor will continue to rise up the oil passage.

3. The gas vent passage is angled at the top portion of the crankshaft. The center line is the point of zero-pressure, and oil will not be able to cross this line because of centrifugal force. Only refrigerant vapor will cross the center line and exit at the top port.

A cut-apart crankshaft (top right) shows the offset and angled gas vent passage. The crankshaft has 15 critical dimensions, and is machined and polished to bearing tolerances as close as .0001 inches. This is roughly 1/30th the thickness of a human hair.



Section II – Reciprocating Technology



Internal Pressure Relif Valve (IPR) – high pressure protection for a longer life.

Metal to glass hermetic terminal – insulates terminal from steel shell, and prevents electrical and refrigerant/oil leakage.

Pearlitic (super hard) cast iron cylinder liners – superior wear resistance for long life.

Aluminum pistons and connecting rods – lighter weight provides for quicker starts and lower stresses.

Aluminum pump body – dissipates heat faster and runs cooler.

Internal overload – provides over temperature protection caused by (1) low refrigerant pressures or (2) excessive electrical currents resulting from extreme operating conditions. Resets itself, avoiding service calls.

Motor winding insulation – super strong epoxy locks the windings in place and resists erosion of insulation by refrigerant and oil.

Internal Muffler – reduces compressor sound and vibration levels for quieter operation.

Special valve steel – made from one of the world's finest steels, so impact resistant that valve stress is not a problem for the Climatuff®.

Rotolock fittings – unique design makes compressor service quick and easy should it ever be required.

Internal spring mounting – double spring mounting reduces motor vibration and noise. The design is so unique it's patented.

Special oil – specially refined and formulated to keep internal parts lubricated and running smooth.

Heavy steel shell – withstands many times normal operating pressure. Seals oil and refrigerant in – keeps contaminants out.

Plus these features:

- **Positive pressure oil pump**
- **Crankcase heater on selected models**

Section III – Scroll Technology

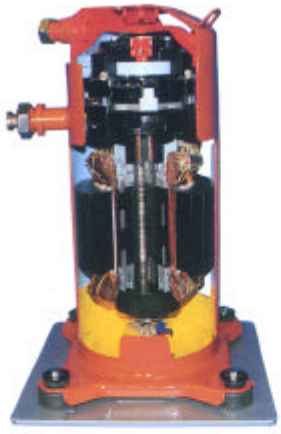
Introduction

The scroll concept was originally patented in the 1890's. It has taken years to perfect the technology to meet the rigorous Climatuff® standards.

Trane Climatuff® compressor quality – that means it is built to meet our specifications. The new scroll technology meets the Climatuff® compressor's qualifications, design criteria, reliability testing, applications testing and production assurance testing outlined in this report. This means proving our reliability and durability in the lab, not in our customers' applications. The Trane Climatuff® compressor philosophy of excellence is continued by this scroll design!

Scroll Compression

The Climatuff® scroll compressor represents a different approach to compression. Rather than a fixed chamber that uses a piston or roller to change volume, the scroll compressor utilizes a moving pocket which is produced by the orbiting motion of the two involutes described in the diagram on the next page.



Climatuff® scrolls waiting for unit assembly.

Section III – Scroll Technology

How Does the Scroll Work

The scroll compression and discharge are smooth and continuous during its full 540 degrees of rotation.

Scroll Gas Flow Pattern

Uncomplicated, Unrestricted Gas Flow Optimizes Efficiency.

Cold, Low Pressure – Entering Gas

Compression in the scroll is created by the interaction of an orbiting spiral and a stationary spiral. Gas enters the outer opening as one of the spirals orbits.

Warmer, Medium Pressure – Interim Gas

The open passage is sealed off as gas is drawn into the spiral.

Hot, High Pressure – Discharge Gases

As the spiral continues to orbit, the gas is compressed into an increasingly smaller pocket.

By the time the gas arrives at the center port, discharge pressure has been reached.

All Stages Working Together

Actually, during operation, all six gas passages are in various stages of compression at all times, resulting in nearly continuous suction and discharge.

Section III – Scroll Technology

Scroll Conformance

In a manner similar to Trane's rugged and highly successful 3-D® commercial scroll compressor (introduced in 1988), the Climatuff® scroll compressor features an innovative method, referred to as "Conformance" for assuring a tight compression pocket. The orbiting scroll is self-adjusting. It moves radially in and out to precisely follow the involute geometry; the fixed scroll moves vertically to maintain optimum contact of the tips. This dual motion capability is the key to achieving the full benefits of the Climatuff® scroll.

The Climatuff® scroll radial Conformance seals compression in much the same manner as the reciprocating Climatuff® piston ring does in the upward stroke. An innovative bushing coupled with centrifugal force is utilized to guide the orbiting scroll involute towards the fixed scroll involute minimizing gas leakage between the involute walls.

The Climatuff® scroll axial Conformance supplements the radial Conformance by sealing the tips using the controlled pressure balance forces to minimize any gaps between involute tips and the mating scroll floor.

Benefits of the Climatuff® Scroll Conformance

The benefits of the Trane Climatuff® scroll Conformance are maximized efficiency, proven durability, low voltage startability and quiet operation.

Climatuff® compressor Conformance increases **efficiency** by continuously compressing the refrigerant gas in each rotation with minimal leakage. Very low leakage is achieved with minimal efficiency-robbing friction because of the tight manufacturing tolerance of Climatuff® compressors.

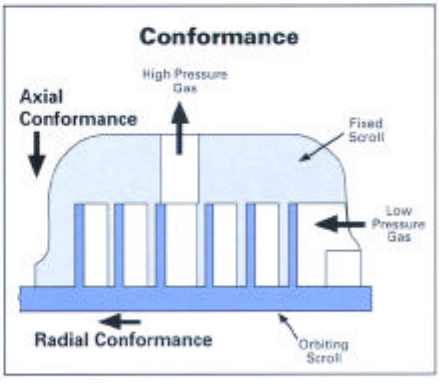
Durability is improved because Conformance plays a key role in the Climatuff® scroll's capability to handle reasonable amounts of liquid flooding and system contamination. The flanks and tips will separate if liquid refrigerant or debris is present allowing the particulate to pass through without harm to the scroll involutes. Contaminants that are flushed through the scrolls are trapped in the system filter driers.

Climatuff® scroll Conformance allows the flanks and the tips to separate when the compressor cycles off and unloads the gas from its high pressure state. This allows for **easy low-voltage starts** every time. Therefore, hard start kits are not required in non-equalizing systems.

Quiet operation is obtained from the smooth continuous compression with little vibration due to the orbiting motion.

The Conformance of the Climatuff® scroll delivers the high quality standards that Trane and our customers demand.

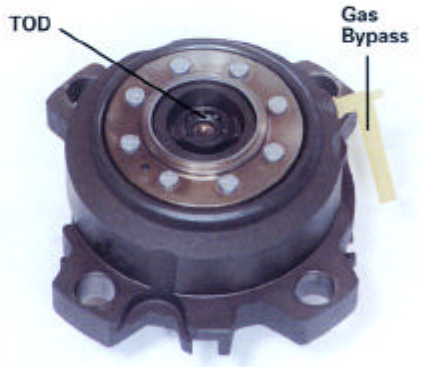
The scroll compression volume is formed by the orbiting relationship between the two involutes. To perform properly, the involutes have to stay in contact the entire length of the involute.



Section III – Scroll Technology

Compressor Stress Capability

The Climatuff® scroll incorporates two permanently lubricated, teflon impregnated bearings to insure bearing life even if sump oil is temporarily washed away from flooding, or during a long off period "dry" startup. In addition, the Climatuff® scroll uses a white mineral oil, similar to the Climatuff® reciprocating for excellent lubrication and long line oil return.



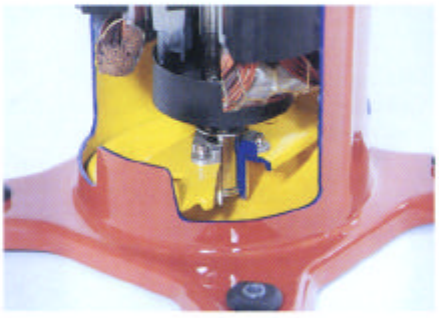
Upper housing with TOD and Gas Bypass. The Thermal Operating Disc (TOD) is a supplemental device that protects scroll tips and motor windings from high temperature/pressure damage.

When discharge temperature exceeds 300 degrees F, the TOD device flows hot gas through the bypass tube onto the IOL. The IOL safety device then cuts power to the motor avoiding damage from excessive discharge temperatures.

A positive pressure oil pump (similar to Climatuff® reciprocating compressors) is used to quickly supply oil to bearings and scroll tips to ensure long life and enhanced pressure sealing. Note oil pickup vanes in bottom of compressor crankshaft.

High Pressure Area shows Muffler, IPR and Temperature Deflector Plate.

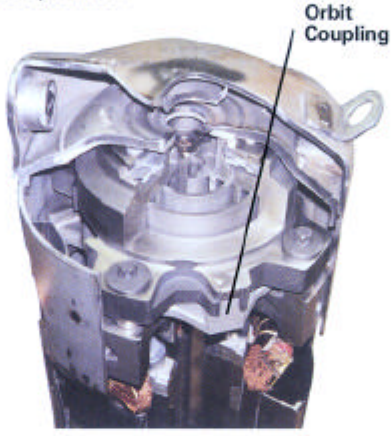
High/low pressure sides of the Climatuff® scroll are separated by a minimum surface to maximize efficiency. The small high side volume of the upper cap acts as a muffler to reduce pulsations of gas.



Section III – Scroll Technology

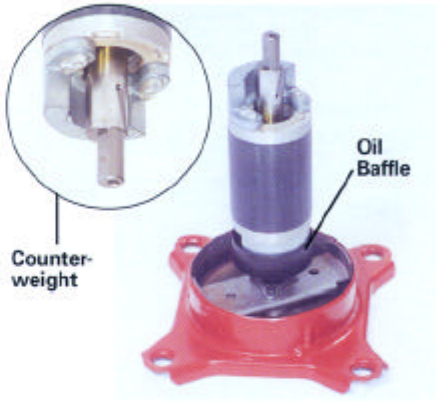
Additional Design Features

The orbit coupling connects the two orbiting scrolls and provides for smooth, quiet operation.



The Climatuff® scroll is designed to be exceptionally quiet in operation. Continuous scroll compression reduces gas pulsations. Balanced rotor counterweights reduce vibration, and shutdown mechanisms eliminate shutdown noise and vibration thus eliminating the need for internal springs.

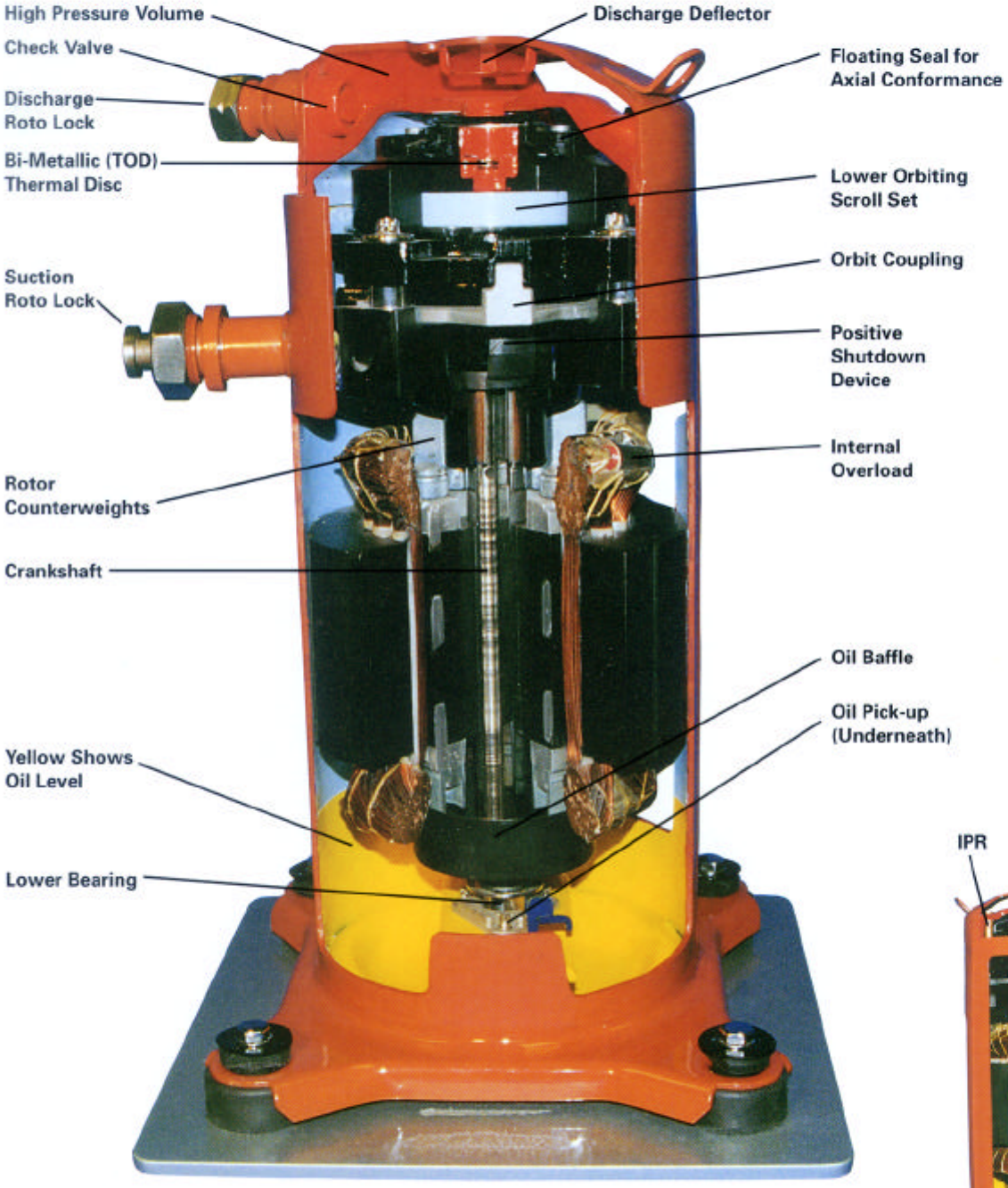
Rubber vibration isolators are also used to ensure no vibration is transmitted to the system.



Climatuff® scroll crankshaft/rotor assemblies use counterweights to reduce vibrations and associated bearing loads. An oil baffle is also used to separate oil from the rotating crankshaft and rotor to reduce oil foaming for improved efficiency and lubrication.

A new method of wire connection is being used on all Climatuff® scrolls. This "terminal plug" positively connects to the terminal header without the use of individual spade connections. This ensures correct wiring, reduces loose connections (and associated overheating), and seals the terminal box against moisture and corrosion.

Section III – Scroll Technology



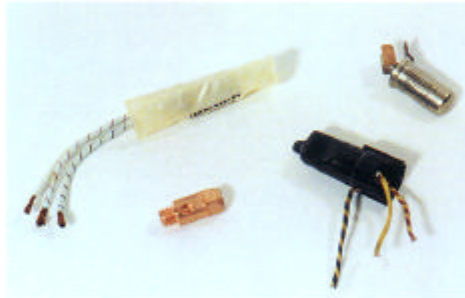
Back Shot

Section IV – Shared Features

Thermal Stresses

Climatuff® compressors have a uniquely-applied protection system using two integrated components: the **internal overload device** (IOL) and the **internal pressure relief valve** (IPR). Since Climatuff® compressors are used in both heat pump and cooling units, Trane has designed the protection system for the higher temperatures and stresses of heat pump operation. The protection system application is designed to allow operation during normal conditions and to prevent compressor damage **during abnormal conditions.**

The Climatuff® compressor's protection system is tamper-proof because both components are located inside the compressor shell. The IOL is mounted directly on the motor windings so it can sense motor temperature without the cooling effect of incoming gas or liquid. The IOL will trip and take the compressor off line on any combination of temperature and current that exceeds motor winding tolerances, even if neither the current nor temperature alone are sufficiently high enough themselves to trip the IOL. This application gives it a high margin of reliability.



The Climatuff® compressor's uniquely-applied protection system. The IPR valves offers high pressure protection. Overloads protect against high current, high and low voltage, low gas flow, loss of charge, high superheat, and system electrical faults.

The IPR valve is mounted in close proximity to the IOL. Should pressure differential between the discharge and suction sides exceed 400-500 psi, the valve will open and hot discharge gas will be drawn across the IOL. The hot gas plus the higher compressor current will cause the IOL to open, shutting down the compressor. With the IPR valve, high pressure is instantly relieved in the compressor shell where no refrigerant loss is possible.

In addition, the Climatuff® scroll supplements the IPR with axial and radial conformance and a TOD to eliminate high pressure stresses and protect against low suction-pressure oil return problems.

New motor frame design increases gas flow to IOL protection device.

Stator with overload.

Electrical Stresses

When the compressor is operating, there can be slight motion of the motor windings created by magnetic flux between the wires. This flexing causes rubbing between adjacent wires, which could wear away the insulation. Bare wires can create turn-to-turn shorts that lead to motor failure. The magnetic forces and flexing increase with current and are exceptionally severe during start-up.

Motor winding insulation erosion is controlled through two methods:

1. Motor winding flex is minimized by specifying an epoxy varnish system which bonds the wires and bundles together.

2. Abrasion resistance is achieved with a double coating of space age "imide" based overcoat.

As good as the bonding system is, Trane motors are designed to pass a torturous surge test in which a 5800 volt spike is applied to the stator. Not only do obvious defects show up, but also minor variations in winding insulation thickness are detected.

The Climatuff® compressor's motor windings feature an epoxy varnish bonding system that dramatically reduces harmful flexing due to magnetic flux between the wires.

Section IV – Shared Features

Chemical Stresses

Climatuff® compressors use a highly refined **white refrigerant oil** with special additives for high and low temperature stability and high pressure stability. The oil has superior lubricity over a wide range of temperatures. The solubility of refrigerant in this white oil blend is less than with pale oils used by other manufacturers. Lower solubility minimizes violent oil foaming on start-up. This reduces oil loss and provides rapid establishment of oil flow to the bearings.

The Climatuff® compressor's special white oil blend is unique to the industry. It maintains its lubricity and viscosity at extreme temperatures and prevents violent oil foaming on start-up.

Some of the pale refrigerant oils used in the industry tend to "coke" (carbonize) on the valves at high temperatures. This coking action leads to loss of efficiency and capacity that the owner will see as climbing utility bills. Coking can eventually lead to compressor failure as the valve cannot seat properly with the carbon build-up. Climatuff®'s high temperature oil additive helps prevent coking.

Serviceability

In addition to being very efficient and reliable, Climatuff® compressors have some beneficial service aspects.

All Climatuff® compressors feature highly reliable **Rotolock mechanical fittings**. Rotolock fittings provide for easy service and replacement because there is no brazing or cutting required. They eliminate the safety hazards that can exist when unbrazing a compressor with a torch. In addition to ease of connection and safety, Rotolock fittings minimize contaminants such as copper chips, welding slag, and other foreign materials because there is no brazing involved.

Climatuff® compressors feature reliable Rotolock fittings. Trane Product Service records show the annual field leak rate to be less than .001 percent.

All Climatuff® compressors feature a **lifting lug** welded to the shell to make lifting easier. Trane compressor engineers originally developed a one time acid test kit for checking unsafe system acid levels. By testing an oil sample from the suction port of a failed compressor, the serviceman can tell if he needs to install a suction line drier.

Using the acid test kit, the serviceman knows if a suction line drier is needed.

Section V – System Testing

Sixteen weeks in SEET = five years of stress in the field. In this unique test, system quality and performance are measured and managed.

This is a continuous flood back test in Trane's compressor life test facility. "Snowball" has been undergoing this test since 1972. The purpose of the test is to demonstrate the reliability of Climatuff® compressor's under conditions like low indoor airflow or system overcharge.

Scroll 500/100 High Pressure Mechanical Stress Test.

Climatuff® Compressor Heritage: Relentless Testing ...

We are different because of our own in-house expertise of compressor applications and reliability testing. We reliability-test compressors in the actual matched units prior to production. SEET Tested!

In addition to using industry standard application guidelines, we develop our own tests based on field experience and in-house testing. This has led to continuous application and design changes and improvements for Trane Climatuff® compressors.

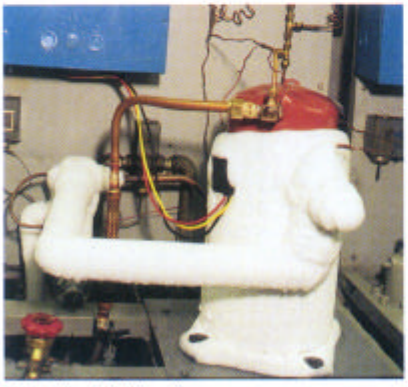
All Climatuff® compressors are designed to tolerate most extreme applications – from Canada to Florida to Arizona. A reliable compressor designed for extreme heat pump application must be able to overcome higher operating temperatures, liquid refrigerant flooding, adverse electrical stresses, and the stress of long operating hours. Climatuff® compressors are designed to handle those tough conditions. All these features benefit the air conditioning design as Trane uses the same rugged heat pump designed compressor in its air conditioners as well.

Every Climatuff® compressor returned from the field is cut apart and analyzed to identify possible failure trends so appropriate corrective action can be implemented.

Section V – System Testing

New SEET

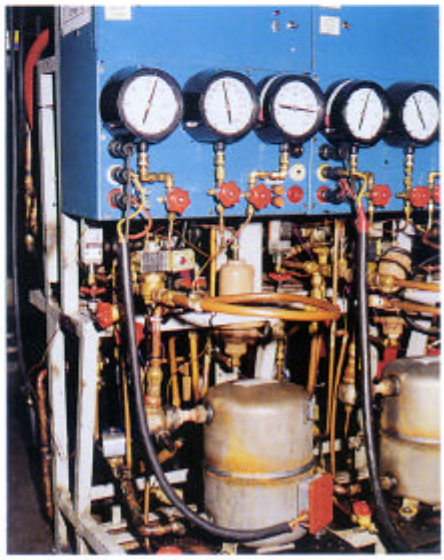
400/100 ten seconds on/off test.



Iceball with "Hot" cap.

All critical components go through three tiers of testing: as a component, as the compressor, and as a "system." For quality assurance, Climatuff® is tested and re-tested in Trane's unique System Extreme Environmental Test Center (SEET). A multi-million dollar facility, SEET allows engineers to measure and manage a system's quality and performance with a sixteen week torturous test period in which five years of field stress can be duplicated. After each test period, each unit is disassembled and its compressor is cut apart and analyzed. Engineers examine for signs of stress and unusual wear. No manufacturer in the industry goes to these lengths to ensure compressor and system quality.

In addition to SEET (System Extreme Environmental Test) testing, other parts of the Climatuff® compressor Qualification Standards process include:



For future – alternate refrigerant test at 800/167.

Climatuff® Application Tests/Critera

Oil Management

- Loss of charge testing in cooling and low ambient heating
- Long line/rise field tests designated

Motor Protection

- Motor/IOL protection includes locked rotor, maximum load trip, stuck start relay
- IOL cycle life confirmation on "Monitor" Stand
- Motor temperature "mapping" on SEET
- System evaporator and condensor fan failure criteria

Mechanical Durability

- A 5-mode accelerated Life Test including start/stop, high load, floodback, high pressure ratio and defrost simulation
- Life Test charge tolerance
- Shipping vibration and drop test

Sound Acceptability

- System/compressor/fan db ratings and "panel" acceptance
- Transient sounds – shutdown, startup, defrost
- Discharge gas pulse measurement

Miscellaneous Testing

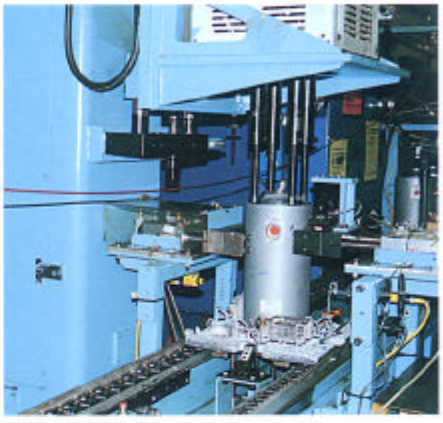
- Low voltage startability
- Compressor driven tubing vibration
- Field testing at employee homes and selected extreme locations.

Hi Rise Application – St. Pierre, Naples, FL.

Section VI – Manufacturing and Testing

Low Voltage Start.

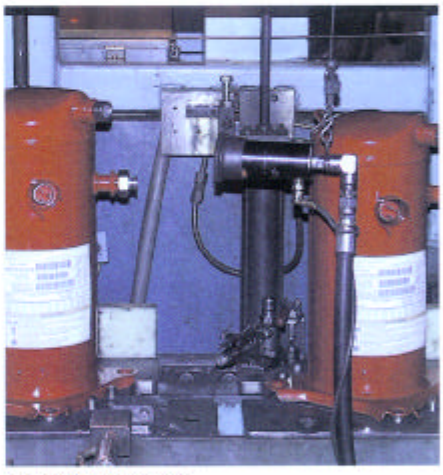
Reciprocating and Scroll Assembly Line Qualification Continues To Maintain Climatuff® Compressor Standards ...



Torquing down scroll assembly.

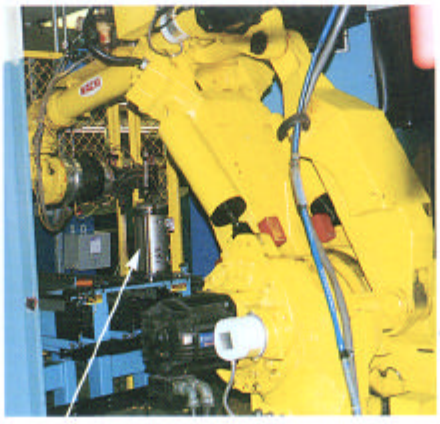
100% Quality Checked.

Oil and Test.

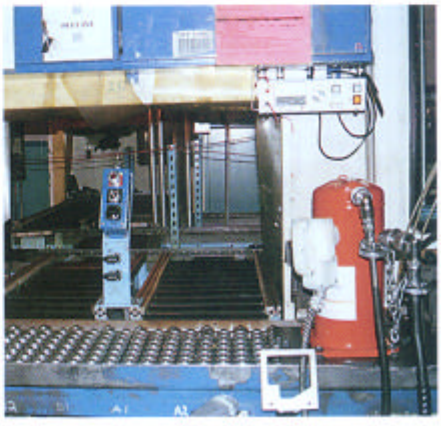


Burst Station Test.

Evacuation Loop.



Robot welding top cap onto scroll.

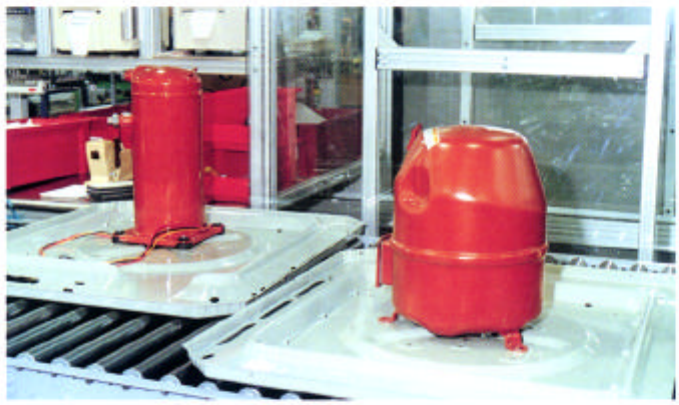


End of line run and sound test.

Section VI – Manufacturing and Testing

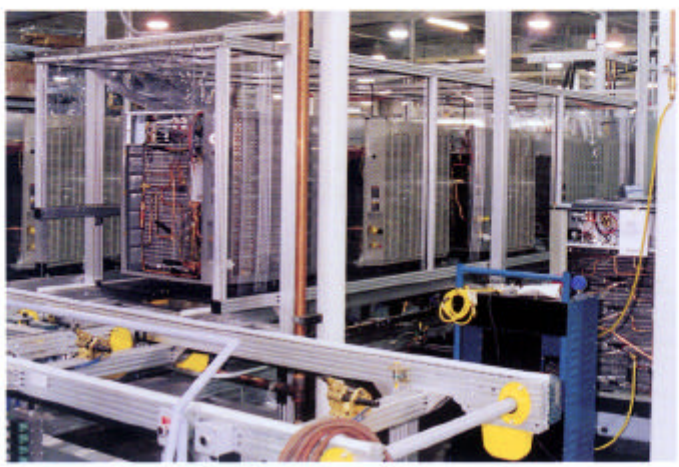
Climatuff® compressor standards include matching the correct compressor to the right outdoor product ...

... The Climatuff® tradition continues!

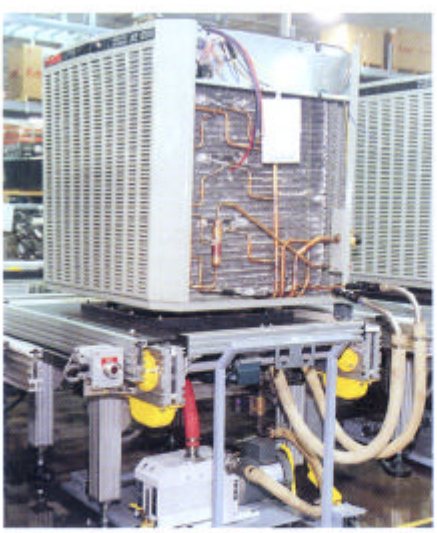


New production line assembly.

Outdoor Production Testing



Helium Leak Test – will detect smallest of leaks.



Vacuum Pumps – Pumped down to a "no moisture" level.

Coil Dunk Tank: *We catch any leaks before you do ... a .001 leak rate on coils!*

Final Check Test.

Section VII – Climatuff® Compressor Summary

Compressors Results And Conclusions

Trane's Climatuff® compressors are among the world's foremost design because of the Climatuff® philosophy. Our compressors are designed to use a minimum of system protection; to "stand alone." This is easy to say but difficult to achieve. It requires a thorough understanding of the system – the Trane Way of Life!

It requires innovative compressor design – a Trane strength. It requires accelerated stress testing to pre-determine field reliability in the laboratory – a Trane strength. It requires unique in-process testing in both compressor assembly and unit manufacturing to assure the design quality is achieved on every single unit/compressor built – a Trane Strength!

Climatuff® motor and protection systems (shared by reciprocating and scroll) are designed to protect the compressor under all adverse operating conditions.

- Climatuff® compressor's epoxy varnish bonding system prevents motor winding flexing and serves as a good electrical insulator. The "Imide"-based wire insulation is also highly resistent to high temperatures, chemicals and abrasion.
- Climatuff® compressor's Internal Overload protects against high current, high and low voltage, low gas flow, loss of charge, high superheat and system electrical faults.
- Climatuff® compressor's Internal Protection Relief valve provides high pressure protection.

Climatuff® compressors are designed to tolerate liquid refrigerant. The Climatuff® reciprocating compressors utilize a large shell, a discharge line in the oil, a high suction inlet and the motor windings to minimize liquid refrigerant in the cylinder. The fully supported ring valves have high tolerance to liquid.

The Climatuff® scroll compressor uses conformance which allows the scrolls to separate and pass liquid through without damage.

Both Climatuff® compressors utilize the crankshaft as a built-in oil pump. The Climatuff® scroll's positive pressure oil pump is used to quickly supply oil to bearings and scroll tip to ensure long life and enhance pressure sealing.

The Climatuff® reciprocating compressor's crankshaft doubles as a positive, non-directional, centrifugal oil pump providing a constant oil supply to the bearings when the compressor is running.

The Climatuff® compressor's unique white oil blend maintains lubricity and viscosity at extreme conditions and prevents violent oil foaming on start-up.

The Climatuff® compressor's rotolock fittings provide the base of connections, eliminate unbrazing hazards, and minimize contaminants.

Because of the Climatuff® compressor's reliability, Trane was the first manufacturer to offer a 10-year warranty on the compressor as part of its XL 1200 series of air conditioners and heat pumps. Designed for durability, manufactured to precise specifications and tested to extremes, Climatuff® compressors set the industry standard for reliability, and quality – the Trane Way of Life!

It's Hard To Stop A Trane.®

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An American Standard Company

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