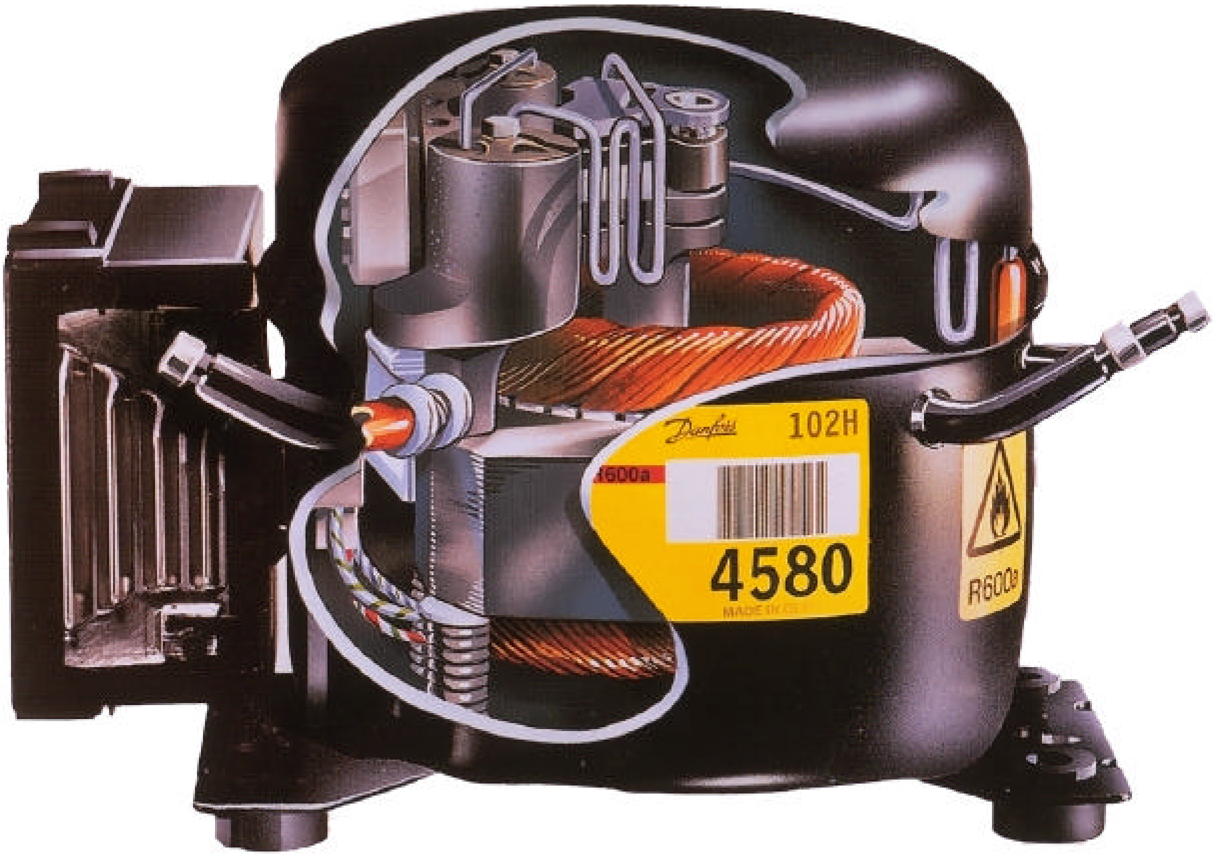
Compressors

VARIABLE SPEED DRIVE COMPRESSORS
TLV and NLV



TLV5K compressor

How to start?

July 2000 CU.58.A2.02

General:

The Danfoss variable speed compressors TLV and NLV serve the possibility to adjust the refrigeration capacity according to the load by controlling the motor speed.
The compressors are highly optimized with very high motor as well as mechanical efficiency. Tests have shown improvements in energy consumption up to 40 %, depending on the system design.

Application:

The TLV-K and NLV-K compressor programme is designed for nominal voltage 220-240 Volt at frequency 50-60 Hz and refrigerant R 600a.
The TLV-F compressor programme is designed for nominal voltage 220-240 Volt at frequency 50-60 Hz and refrigerant R 134a.
The compressors are primarily designed for use at low evaporating temperatures (LBP) in domestic refrigerators and freezers, or similar appliances, with a demand for extremely low energy comsumption.

Selection:

Controlling the compressor speed means that the compressor selection is different to standard compressors. The model is chosen according to the capacity at max. speed. This capacity will cover the load at max. ambient temperature or at fast freeze. This max. capacity will be chosen similar to the rated capacity of a standard single speed compressor for the same appliance. During normal operation the compressor runs at minimum speed, giving the highest COP, and during peak load operation at maximum speed. The advantages by doing this are:

- a smaller compressor in terms of displacement is needed
- longer running periods at load conditions with higher evaporation temperature and lower condensing temperature, giving higher compressor COP. Overall system efficiency increases
- lower rpm - lower noise level

Variable speed programme:

The compressor programme is under constant consideration and extension of the capacity range is under development.
The performance data will be updated in the individual datasheets, to be found on the homepage www.danfoss.com/compressors .
Evaluation samples for special purposes, and refrigerants other than R 600a and R 134a, are possible to establish in development cooperation projects.

Design:

Electrical:

The compressors are equipped with permanent magnet rotors (PM motor) and 3 identical stator windings. The electronic unit is mounted directly on the compressor and controls the PM motor.

Mechanical:

All other components are based on our highly energy optimized compressor programme.
All R 600a compressors are charged with mineral oil and are only approved for use with this oil and refrigerant. An orange stripe and the text 'R600a' on the compressor label identify the compressors for this application.
All R 134a compressors are charged with ester oil and are only approved for use with this oil and refrigerant. A blue stripe and the text 'R134a' on the compressor label identify the compressors for this application.

Design limits:

In order to secure the lifetime of the compressors, the appliances have to meet some design criteria.
The compressor has to start and work properly through pressure peaks obtained in the highest ambient temperature and lowest obliging voltage.
At this peak load the condensing temperature must not exceed 70°C.
At stable operation conditions the condensing temperature must not exceed 60°C.
These limits are the same for our fixed speed compressor ranges and secure a protection of valves, gaskets, oil and motor insulation

Electronic unit:

The variable speed compressor motors are electronically controlled. No attemp must be made to start the compressor without a complete electronic unit, as specified in the data sheet for the compressor type in question.
The electronic unit has a built-in overload protection as well as thermal protection. In case of activation of this protection the electronic unit will protect the compressor motor as well as itself.
When the protection has been activated, the electronic unit automatically will restart the compressor after a certain time.
The electronic unit provides the compressor with high starting torque (HST) which means that a pressure-equalizeation of the system before start is not necessary.

Power supply connections :

Mains is connected to terminals L and N. To facilitate connection with other units the control unit is provided with parallel connector pins to L and N. Protective earth is connected to the compressor shell.

Thermostat connections :

The Danfoss control units for variable speed compressors contain 3 interface modes for thermostats. This includes the standard connections of fixed speed compressors (see description a) to simplify the integration of the variable speed compressors in existing appliances.

All connection terminals are 6.3mm spades. RAST5 connectors can be used.

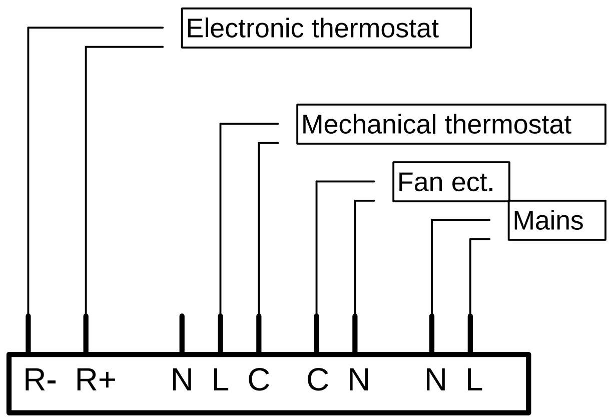


Figure 1: Connection terminals

a) Standard mechanical switching type of thermostat with a 220V on/off signal

The thermostat switch is connected to the terminals L and C - see figure 1. The compressor runs in 'adaptive control' mode, see description: Adaptive control. A fan can be connected to N and C and will be started and stopped with the compressor.
Thermostats with integrated heating resistors, for avoiding cross ambient switching, can not be used, as the input is of high impedance. A small current flows through the resistor when contacts are open. Thus the thermostat would always be interpreted as on.

b) Thermostat with DC signal out (5V, max. 15V)

DC signal (on - off) is connected to terminal R+ and R-, which are reinforced isolated in the compressor control. The compressor control is in 'adaptive control' - see description: Adaptive control. A fan can not be connected.

c) Electronic thermostat with frequency output (5V, max. 15V)

A square signal is connected to pins R+ and R-, which are reinforced isolated in the compressor control. The refrigerator thermostat is to supply the Danfoss compressor electronic unit with a square signal, with min. pulse width 200 µs. A fan can not be connected.

- If a frequency signal with more than 100 Hz is applied, the compressor goes into 'external reference control' mode.
- The compressor speed then will be controlled according to the applied frequency, multiplied by 10, see figure 2 (e.g. 230 Hz will result in a speed of 2300 rpm).
- If a frequency above the value for maximum speed is applied, the compressor will work at max. speed.
- If a constant DC signal is supplied immediately after a frequency signal, the speed will be maintained until a new frequency is supplied or until the DC signal goes low.
- A frequency signal below 200 Hz will stop the compressor. Restart frequency must be above 203 ±2 Hz.

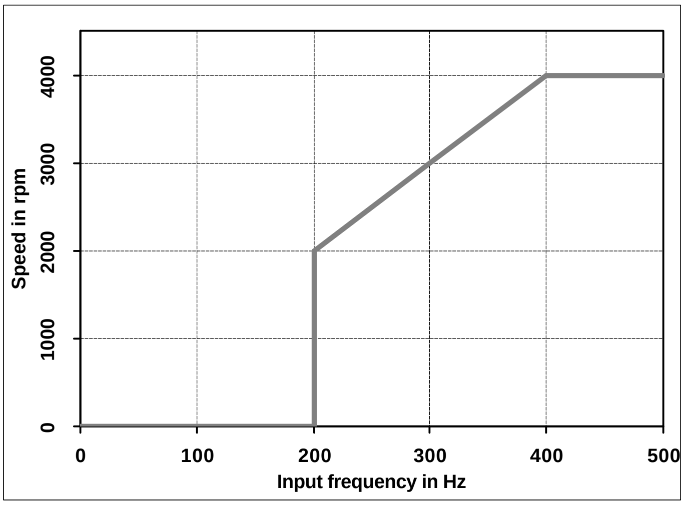


Figure 2: Speed control with external frequency signal

Adaptive control (AEO Adaptive Energy Optimizer)

The controller in the electronic unit takes over the RPM management by using the built-in algorithm. The strategy targets for the lowest possible RPM at which the refrigerating system will work properly, because COP is highest at low speed.

- First start of the compressor after mains connection will be at 3000 rpm, on thermostat signal on.
- In the succeeding cycles the compressor will start with a speed slightly below the previous cycle, according to figure 3, as long as the running period is below 60 min. Following this pattern the compressor will reach the lowest possible value, which is set to 2000 rpm, after a series of thermostat cycles.

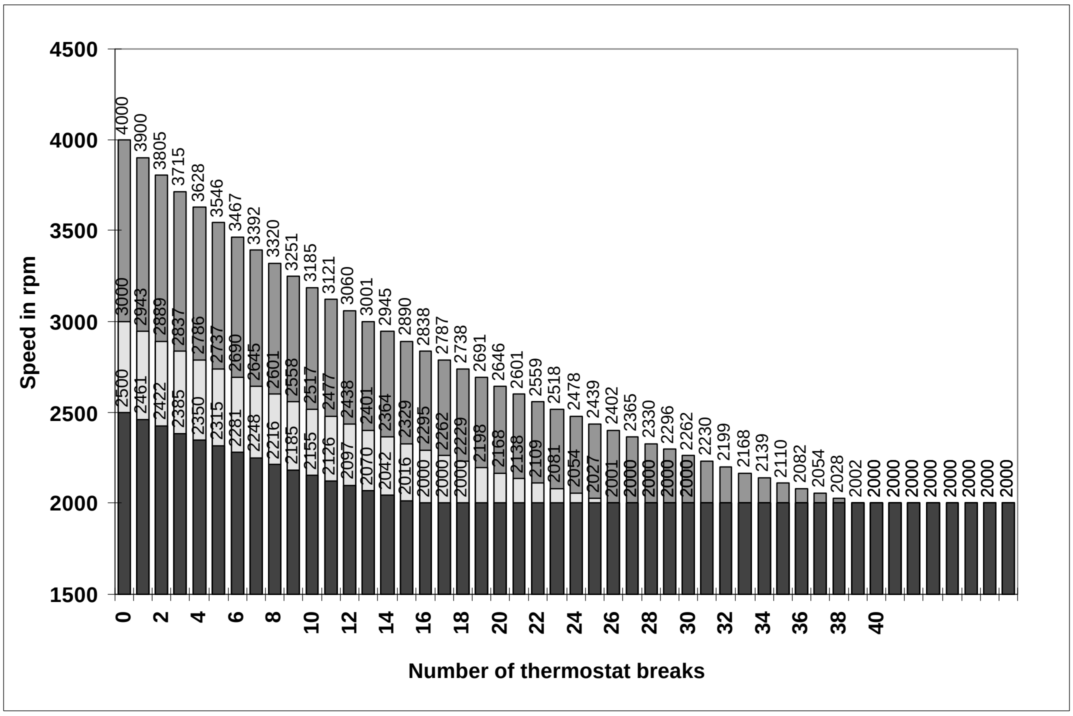


Figure 3: AEO step down examples

- If the running period however exceeds 60 minutes, the speed is increased according to the scheme in figure 4.
- After a total duty cycle of 75 minutes the control unit will increase the speed first time, then successively every 15 minutes until the max. speed is reached. Following this pattern the compressor will reach the maximum speed within a certain time, depending on the start speed, if not recieving an 'off' signal. This increase will normally occur at high ambient temperature or at loading of a freezer for freezing.

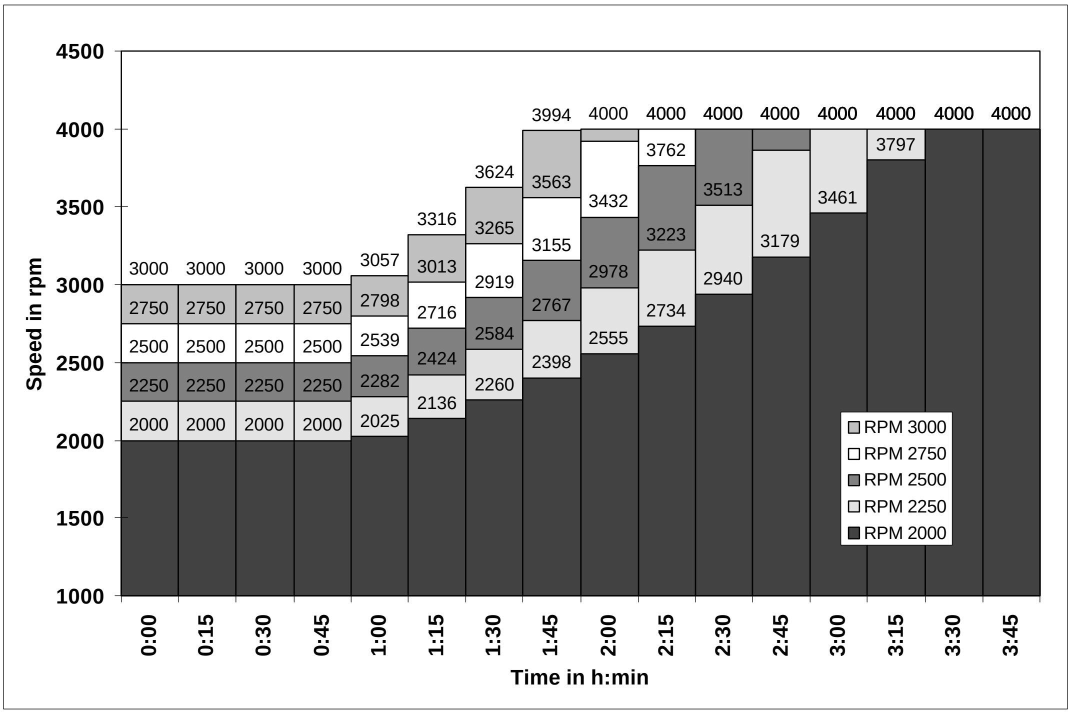


Figure 4: AEO step up examples

Charge determination should be done at fixed speed, with a frequency according to the speed needed, like in the description at c).

Delivery:

The compressors are delivered seperated from the electronic units.
In quantities the compressors are delivered on standard Danfoss pallets with the dimensions 1144 x 800 mm containing 125 pcs TLV or 80 pcs NLV per pallet.
The electronic units are delivered in boxes or multiboxes.

Mounting:

In general the compressors can be mounted as normal compressors. The first generation of the variable speed compressors however has a slightly enlarged space need, in the area of the electronic unit. This may force the use of 'snap-on' mounting accessories. This space will be reduced in future electronic units generations.
The electronic unit is mounted and fixed with two M 3.5 screws.

Approvals:

Compressors are approved according to EN 60335-2-34 (partly pending).

Performance data :

July 2000, partly preliminary

R 134a compressors

Capacity in W at EN 12900/CECOMAF conditions

Compressor	TLV5F	TLV6F	TLV7F
2000 rpm	70.1	74.5	90.0
2500 rpm	85.7	90.4	111
3000 rpm	100	105	128
4000 rpm	129	132	153

Capacity in W at ASHRAE conditions

Compressor	TLV5F	TLV6F	TLV7F
2000 rpm	95.0	102	123
2500 rpm	117	124	151
3000 rpm	136	144	175
4000 rpm	176	181	210

R 600a compressors

Capacity in W at EN 12900/CECOMAF conditions

Compressor	TLV5K	TLV6K	TLV7K	TLV8K	TLV9K	NLV11K
2000 rpm	39.6	46.0	58	64.0	74.1	97.7
2500 rpm	49.2	56.9	70	79.2	91.0	122
3000 rpm	58.3	67.0	80	92.4	104	144
4000 rpm	74.8	84.9	98	113	126	180

Capacity in W at ASHRAE conditions

Compressor	TLV5K	TLV6K	TLV7K	TLV8K	TLV9K	NLV11K
2000 rpm	53.5	61.8	75	85.6	99.0	130
2500 rpm	66.7	76.3	91	106	122	164
3000 rpm	79.0	90.0	104	124	139	194
4000 rpm	101	114	127	152	168	243

Test conditions	EN12900/CECOMAF	ASHRAE
Evaporating temperature	-25°C	-23.3°C
Condensing temperature	+55°C	+54.4°C
Ambient and suction gas temperature	+32°C	+32°C
Liquid temperature	+55°C	+32°C

Static cooling, 220Volt 50Hz

General data:

Refrigerant	R134a			R600a					
Compressor	TLV5F	TLV6F	TLV7F	TLV5K	TLV6K	TLV7K	TLV8K	TLV9K	NLV11K
Code number	102G 4585	102G 4685	102G 4785	102H 4580	102H 4680	102H 4780	102H 4880	102H 4980	105H 6930
Electronic unit	105N4001								105N4201

Application	LBP	LBP/MBP
Evap. temp. range	-35 to -10 °C	-35 to 0 °C
Voltage range	198-254 Volt 50-60 Hz	
Starting torque	High starting torque	
Max ambient	43°C	
Compressor cooling	Static	

Displacement cm^3	5.1	5.7	6.5	5.1	5.7	6.5	7.8	8.8	11.15
Oil quantity cm^3	180			180					320
Max. refrig. charge	400 g			150 g					
Weight compressor / electronic unit kg	7.9 0.6								10.8 0.6
Height mm A B	170 166								197 190
Suction conn. C	6.2 ±0.09 mm								
Process conn. D	6.2 ±0.09 mm								
Discharge conn. E	5.0 +0.12/+0.20 mm								

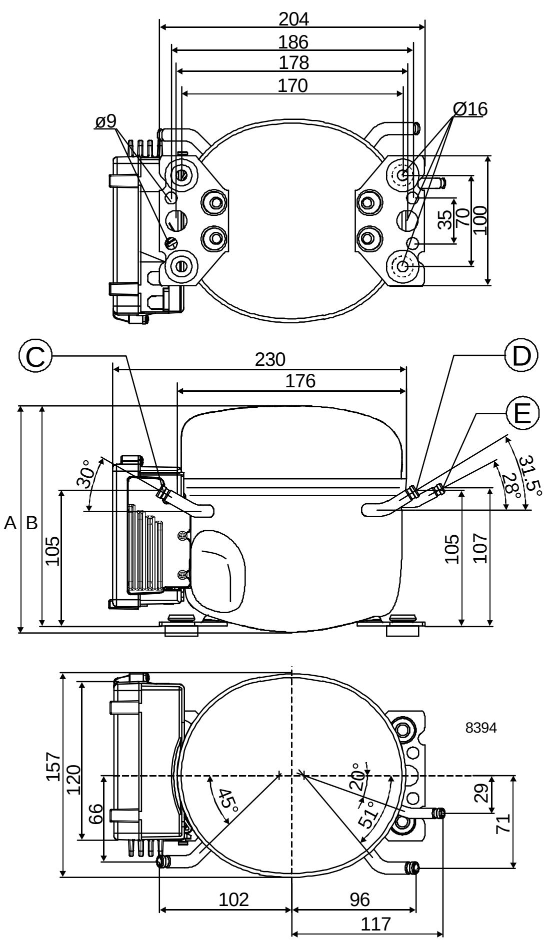


Figure 5: TLV dimensions

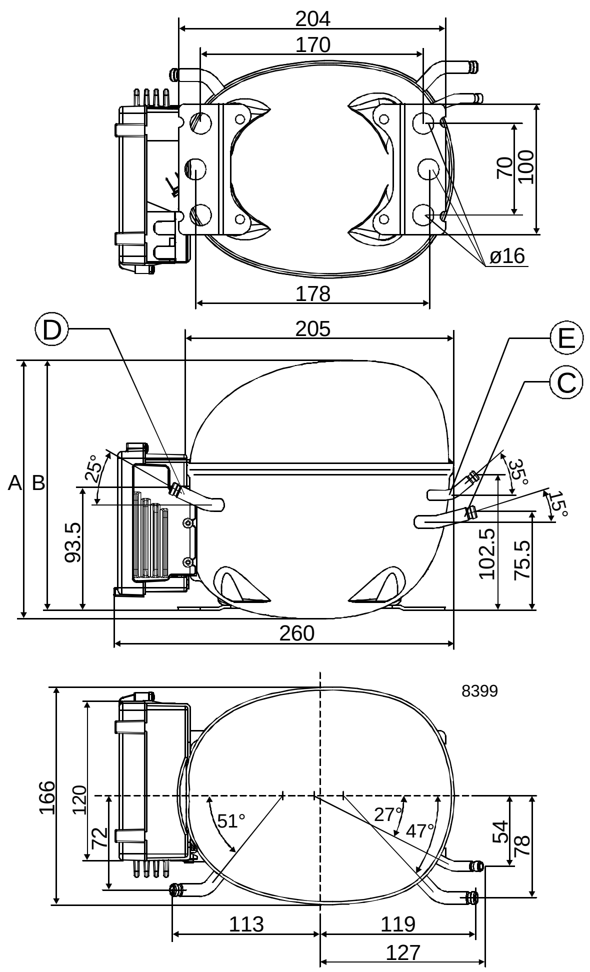


Figure 6: NLV dimensions

Test equipment specifications:

Power consumption

Because of a current shape different from standard compressors, as described more in detail in 'Current consumption shape', measuring equipment for energy consumption has to meet extended specifications. The higher frequency parts of the current give a demand for a bandwidth of at least 5 kHz for the energy consumption measurement equipment, to get accurate measurements.

We recommend following data:

Minimum bandwidth	10 kHz
Power factor capability	<0.2
Peak current capability	15 A

Results coming from equipment with unsatisfactory bandwidth are not predictable. A systematic deviation of several percent is easily possible to get, resulting in higher or lower values.

Speed

When testing compressors on a calorimeter, an accurate frequency signal source has to be used, e.g. a laboratory frequency generator. Testing at a different speed, slightly higher, gives remarkable differences, and non comparable results.
When testing at lowest possible speed, 2000 rpm, the control signal has to be put above the startup frequency of 203 ±2 Hz, then carefully adjusted down to 200 Hz, because the electronic unit stops the motor below 200 Hz. In this way a test at 2000 rpm to 2005 rpm should be possible.

Cut in speed	2030 rpm
Cut out speed	<2000 rpm

For charge determination in appliances, the speed should be fixed with a frequency signal source also.

Current consumption shape:

The PM motors used in the TLV compressors are feed with a switched DC current. The DC part is feed via a controlled rectifier bridge. This gives current peaks with a shape very different from a sine curve and additionally a phase angle between voltage and current, resulting in a remarkable power factor.
At maximum speed and high load the phase angle is very low, but at low speed the current peak becomes narrower and the phase angle is large. Especially at low speed the best energy consumption is possible, so here the best measuring accuracy is necessary to give reliable results.
Future NLV electronics will work slightly different.
The next figures show current peaks of a TLV compressor at low speed and high speed, taken from measurements with a fast digital oscilloscope, relative to the 230V 50 Hz AC voltage supply sine curve.

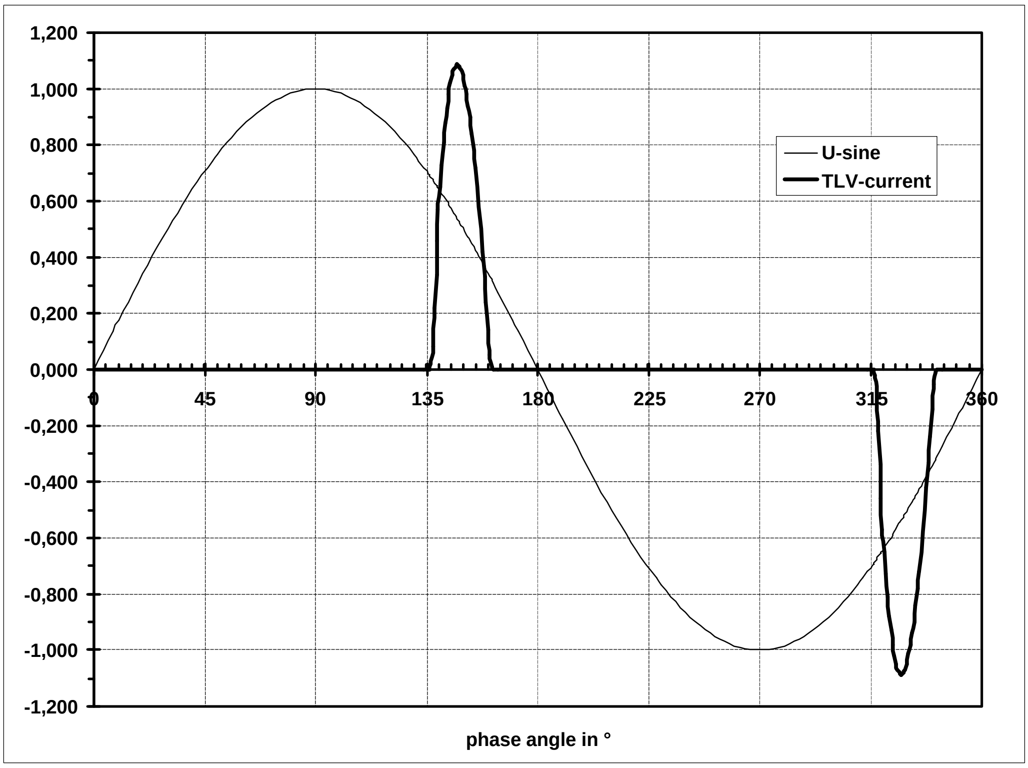


Figure 7: Current curve at 2000 rpm

Curves are:

U-sine	- sine voltage supply shape
TLV current	- current consumption shape

Test equipment should be capable of measuring up to 10 kHz to get accurate results. Digital wattmeters usually have a bandwidth of 10 kHz or more.

The phase delay between voltage and current can add some difficulties to equipment also, as it is relatively large at low speed and low load, as seen in figure 7.

The peak shape of the current can possibly lead to wrong measuring range in automatic range select mode, as the ratio of peak value to RMS mean value is high. In the figure shown for 2000 rpm the ratio is approx. 3.6, while a ratio of approx. 1.4 is found on sine shaped curves.

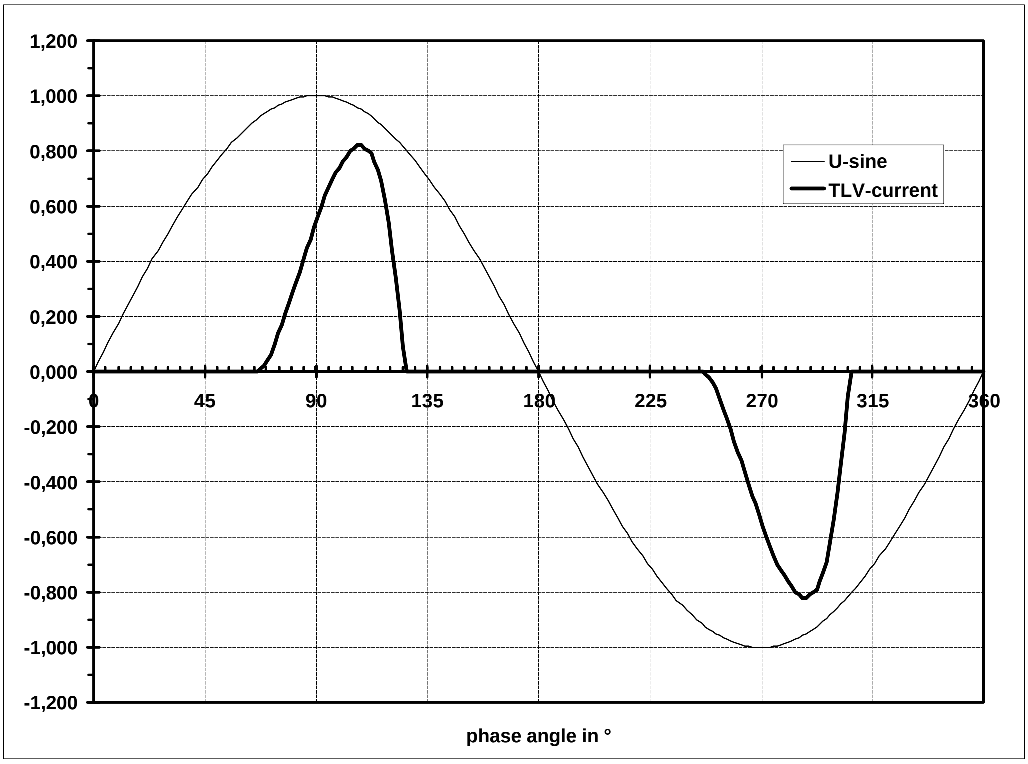


Figure 8: Current curve at max. speed

Voltage stabilization:

When operating a single appliance with a variable speed compressor on an automatic voltage stabilizer in a laboratory, the stabilizer can produce very strong voltage fluctuations, because of the current shape being very different to sine. Using an additional load, e.g. a normal incandescent lamp or other resistant load, the stabilizer should work normal again.

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