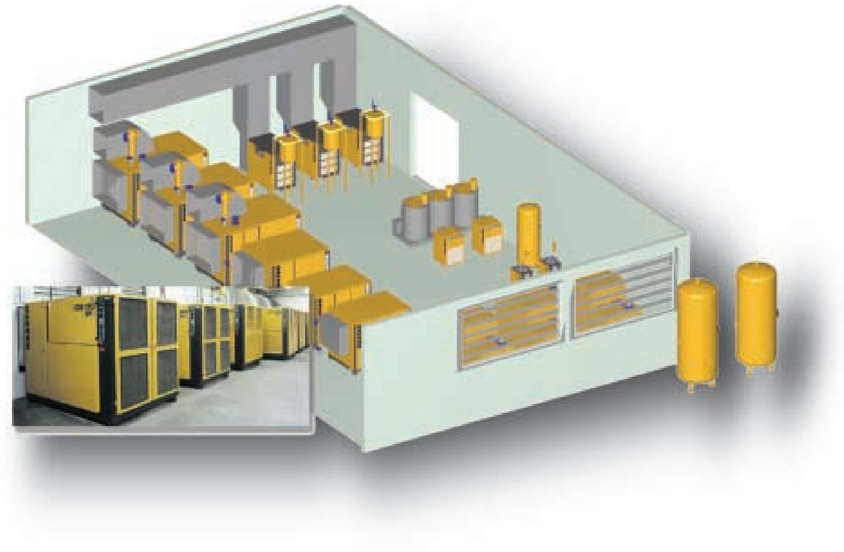
KAESER COMPRESSORS

COMPRESSED AIR

Fundamentals, tips and suggestions on compressed air technology; compact, clear and plainly written.



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Further information and tools for correctly planning your compressed air supply system can be found on the Internet at

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Services/Planning and consultation

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Foreword

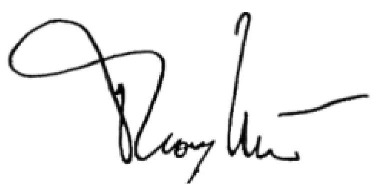
In almost every field of industry, compressed air is now recognised as an essential energy medium and, with so much depending on it, its availability in the right quantity, pressure and quality must be beyond doubt.

The drive for increased efficiency in compressed air production and use started jointly in the Frauenhofer Institute for System Technology and Innovation, the German Energy Agency, the German Machine Tool Manufacturer's Association and a group of prominent enterprises in the compressed air branch. As one of Germany's leading makers of compressors and air systems, Kaeser is a prime mover in this campaign that is having repercussions throughout the world.

The contents of this booklet was originally published as a series of articles in the house magazine KAESER REPORT and gives not only the hard facts of compressed air technology but also advice and tips gleaned from decades of experience.

We hope you find it interesting reading and helpful in improving your efficiency and cost effectiveness in the production and use of this versatile energy medium.

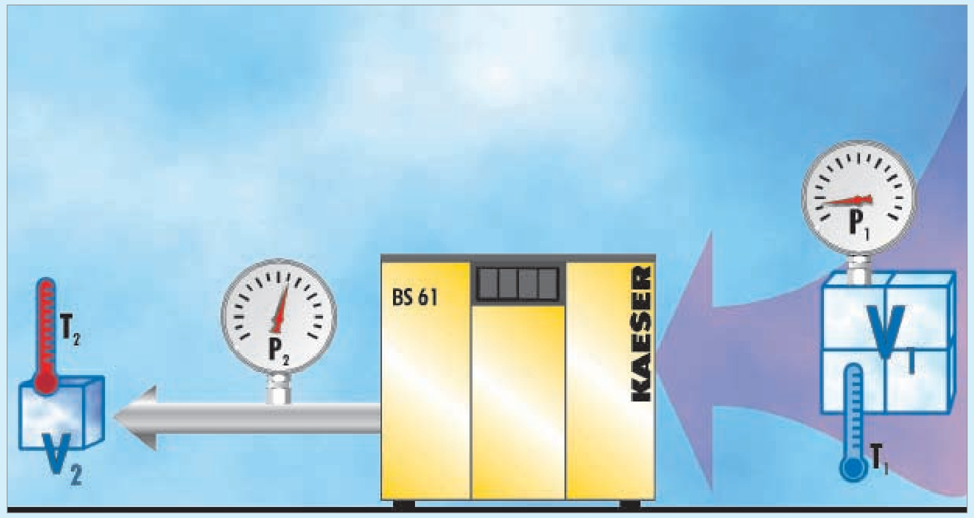
Carl Kaeser



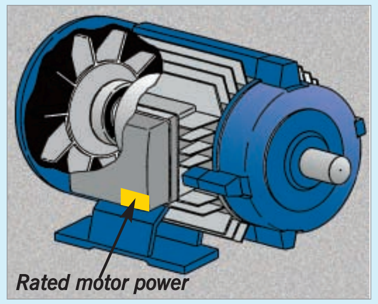
Thomas Kaeser

1. What is compressed air?

It's the same with compressed air as with everything else in life, the cause may be minute but the result is often overwhelming – both in the positive and in the negative sense. We hope that our 'Compressed Air' brochure will help you to produce compressed air as an energy carrier more efficiently in the future, using experience and tips gained in general practice. The main point is to save power costs and thus your money. It's possible that in the long run our tips will save you more money than the clever advice of your investment consultant!
In this chapter we will explain four terms used in compressor technology and the things you should watch for in connection with these terms.



1. Free air delivery
The free air delivery (FAD) of a compressor is the expanded volume of air that the compressor forces into the air main (compressed air network). The correct method of measuring this volume is determined in ISO 1217, Sect. 1, Annex C standards. Also, the CAGI-Pneurop



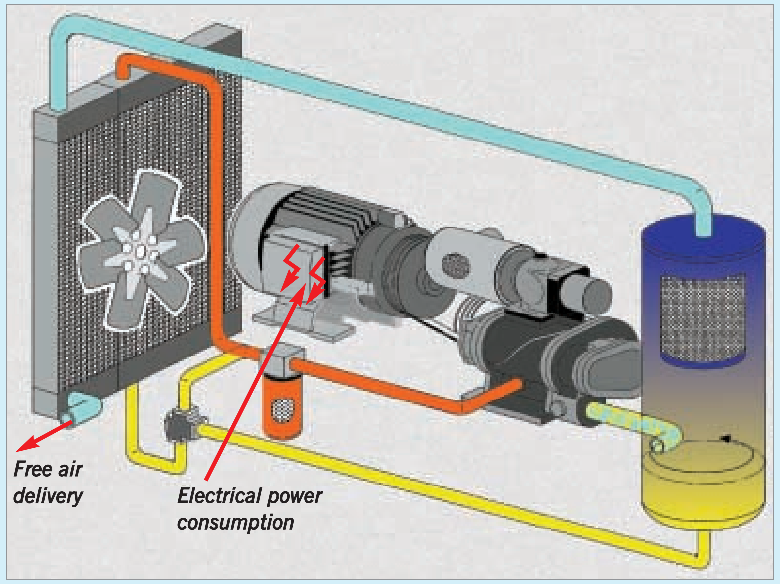
PN 2 CPTC 2 recommendation can be used.
Proceed as follows to measure FAD: firstly, the temperature, atmospheric pressure and and the humidity of the air is measured at the inlet of the complete package. Then, the maximum working pressure, the compressed air temperature and the air demand at the compressed air outlet of the package is measured. Finally, the volume V_2 measured at the compressed air outlet is referred back to the inlet conditions using the gas equation (see illustration above). The result of this calculation is the FAD of the compressor package. It must not be confused with the FAD of the compressor airend (airend capacity).
Caution!
ISO 1217 on its own only defines

$$V_1 = \frac{V_2 \times P_2 \times T_1}{T_2 \times P_1}$$

the FAD of the airend. The same applies to the CAGI-Pneurop PN 2 CPTC 1 recommendation.

2. Motor shaft power
The motor shaft power is that power that the drive motor mechanically delivers to the motor shaft.The optimum value of motor shaft power at which optimum utilization of the electrical efficiency and the power factor cos φ is achieved without overloading the motor is called the rated motor power. This power is entered on the nameplate of the motor.

Caution! If the motor shaft power deviates too far from the rated motor power then the compressor runs inefficiently and/or is subject to increased wear.



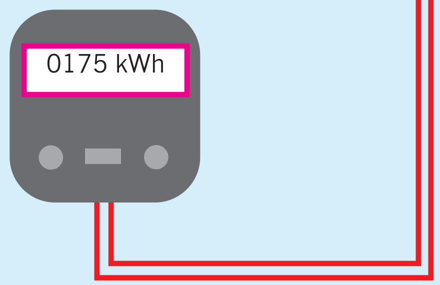
3. Specific energy requirement
The specific energy requirement of a compressor is the relationship between the electrical power consumption and the FAD at a corresponding working pressure. The electrical power consumption is the sum of the power consumption of all drives in the compressor package, e.g. main drive motor, fan motor, fluid pump motor, auxiliary heating, etc.

If the specific energy requirement is needed for an economic appraisal, it should refer to the overall compressor package and the maximum working pressure.
Then, the overall electrical power consumption at maximum working pressure is divided by the package FAD at maximum pressure.

4. Electric power consumption
The power consumption is that power that the drive motor of the compressor takes from the main power supply with a defined mechanical load on the motor shaft (motor shaft power). The power consumption exceeds the motor shaft power by the value of the motor losses. Motor losses also include both electrical and mechanical losses caused by motor bearings and cooling.
The ideal power consumption P is calculated with the formula
$P = V_n \times I_n \times \sqrt{3} \times \cos\varphi_n$

V_n, I_n, and cos φ_n are found on the nameplate of the motor.

5. New requirements for energy-saving drives
Efforts in the USA and Europe to reduce the energy requirements of three-phase, asynchronous electric motors has resulted in various energy conservation acts becoming law in recent years. Kaeser has been supplying rotary screw compressors with motors that comply with these strict requirements since 1998. Users of compressors fitted with these new

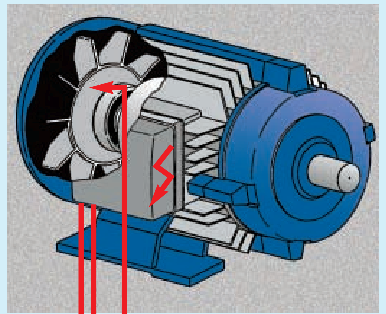


premium efficiency motors benefit from numerous advantages:

a) Lower working temperatures
Heat generation and friction cause internal efficiency losses that can be up to 20 percent in small motors and 4-5 percent in motors upward of 160 kW. In premium efficiency motors however, this heat and therefore energy loss is significantly less. Whereas the increase in working temperature on a conventional motor under normal loading is approximately 80 °C with a temperature reserve of 20 °C compared with insulation class F, the temperature increase of the new motor under the same conditions is only 65 °C with a temperature reserve of 40 °C.

b) Longer life
Lower working temperatures mean less thermal stress on the motor, the motor bearings and the terminal box, resulting in extended motor life.

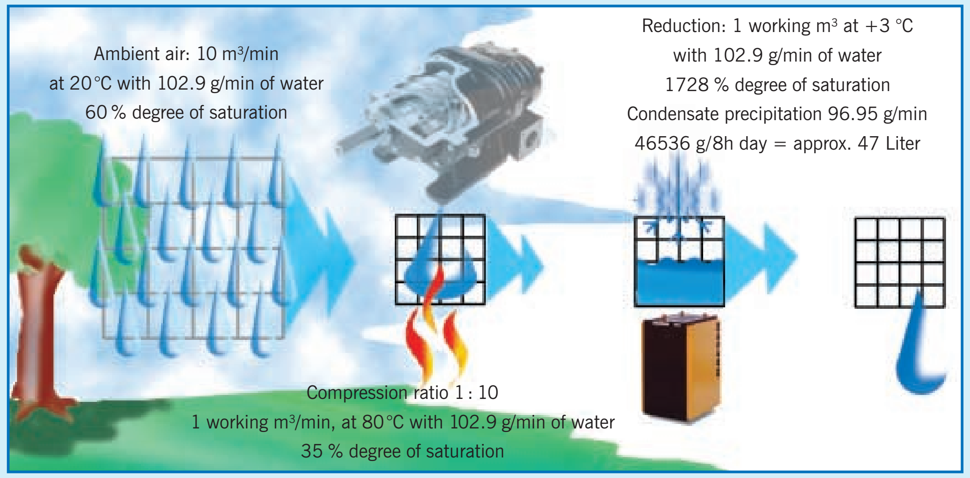
c) Six percent more air for less power consumption
Less heat loss leads to an increase in efficiency and with precise matching of the airend to the motor, KAESER is able to achieve up to six percent increase in delivery and five percent reduction



in specific energy requirement. The result is improved compressor performance with less energy consumed per cubic metre of compressed air delivered.

2. Why do we need to dry compressed air?

The problem is in the air – in the true sense of the word. When air cools, as is the case after compression in a compressor, then water vapour is precipitated. In this way, a 30 kW compressor with a capacity of 5 m³/min at 7.5 bar working under average conditions will "produce" approximately 20 litres of water per working shift! This water must be removed from the compressed air system to avoid damage and production problems. Drying the compressed air is an important part of the air treatment process. You will find valuable information on drying air inexpensively and ecologically in this chapter.



1. A practical example

If a fluid-cooled rotary screw compressor draws in air at atmospheric pressure with a relative humidity of 60 % and an ambient temperature of 20 °C at a rate of 10 m³ per minute, then this air contains approximately 100 g of water vapour. If the air is compressed to an absolute pressure of 10 bar at a compression ratio of 1 : 10, then one working cubic metre is obtained. However, at a temperature of 80 °C after compression, the air could take up 290 g of water per cubic metre. As only approximately 100 g is available though, the air is very dry, with a relative humidity of approximately 35 %, so that no condensate can precipitate. The temperature of the compressed air is reduced from 80 to approximately 30 °C in the aftercooler. At this temperature, a cubic metre of air can only hold around 30 g of water, so that an excess of water of approximately 70 g/min occurs, which condenses and is separated. This means that 35 litres of condensate accumulate over an eight hour working day. A further six litres per day will be separated if a refrigeration dryer is installed downstream. The air is initially cooled down to +3 °C in these dryers and then heated up to the ambient temperature again later. This leads to a water vapour saturation deficit of approximately 20 % and thus to a better, relatively dry compressed air quality.

2. The cause of humidity

Air always contains a component of water. This humidity is dependent on temperature. For example, air at a temperature of +25 °C saturated with water vapour to 100 % holds almost 23 g of water per cubic metre

3. Precipitation of condensate

Condensate precipitates when the air volume reduces and the temperature of the air sinks at the same time. This reduces the capacity of the air to hold water. This is precisely what happens in the airend and in the aftercooler of a compressor.

4. Important terms - briefly explained

a) Absolute air humidity

Absolute humidity is the water vapour content of the air, given in g/m³.

b) Relative air humidity (F_{rel})

The relative air humidity quotes the degree of saturation, that is, the ratio of the real water vapour content to the individual degree of saturation (100 % F_{rel}) of the air. This is variable according to temperature. Hot air can hold more water vapour than cold air.

c) Atmospheric dew point

The atmospheric dew point is that temperature at which the air reaches a degree of humidity saturation of 100% (F_{rel}) at atmospheric pressure (ambient conditions).

Dew point in °C	Max. water content in g/m³
+40	50.7
+30	30.1
+20	17.1
+10	9.4
0	4.9
–10	2.2
–20	0.9
–25	0.5

d) Pressure dew point

The pressure dew point is the temperature at which the compressed air reaches its humidity saturation point (100 % F_{rel}) at its absolute pressure

This means, in the above case, that air under a pressure of 10 bar (a) has an absolute air humidity of 6 g per working cubic meter at a pressure dew point of +3 °C. **To put it more clearly,** if the working cubic metre mentioned is expanded from 10 bar (a) to atmospheric pressure, then its volume increases 10 times. The water vapour component of 6 g remains unchanged, but is now distributed over 10 times the volume. This means that every cubic metre of expanded air only contains 0.6 g of water vapour. That corresponds to an atmospheric dew point of -24 °C.

5. Economical and ecological compressed air drying

a) A refrigeration dryer or a desiccant dryer?

New environmental legislation concerning refrigerants has not changed the fact that desiccant dryers do not provide an alternative to the refrigeration dryer, neither from the economical nor from the environmental point of view. Refrigeration dryers consume only 3 % of the energy that the compressor needs to produce compressed air. In comparison, desiccant dryers consume 10 to 25 % or more. For this reason, refrigeration dryers should always be used in normal cases. The use of a desiccant dryer makes sense, just as before, if extremely dry quality air with pressure dew points down to -20, -40 or -70 °C is required

b) What refrigerant should be used?

CFCs such as R 12 and R22 may not be used any more in new refrigeration dryers. The table below shows the influence of refrigerants on the environment. Up to the year 2000, most refrigeration dryer manufacturers used R 22, a partly halogenated CFC, as an alternative to R 22 with only 5% ozone depletion potential and a global warming potential of 12%. Today, however, the HFC refrigerant 134a is preferred and recommended by authorities because of its nil affect on the atmosphere as a far better alternative to R 22. The advantage of R 134a lies in the possibility of converting equipment previously using R 12 to the new refrigerant without too much effort. Other refrigerants also with 0 % ozone depletion potential such as R 404A and R 407C are now available as alternatives to R 134a but these are blended products and variations in temperature (glide) at which their component parts evaporate and condense result in a global warming potential higher than R 134a as shown in the table below. For this reason, R 407C would only be considered in special circumstances and R 404A, with its relatively low temperature glide is only of interest where high flow rates of 24 m³/min and above are involved.

Refrigerant	Composition	ODP = ozone depletion potential (R 12 = 100%)	GWP = global warming potential (R 12 = 100%)	Temperature glide Possible variation in evaporation and condensing temperature (K)
HCFC R 22	$CHClF_2$	5%	12%	0
HFC R 134a	CH_2F-CF_3	0%	8%	0
Blend R 404A	R 143a/125/134a	0%	26%	0.7
R 407C	R 32/125/134a	0%	11%	7.4

3. Save costs with compressor controllers

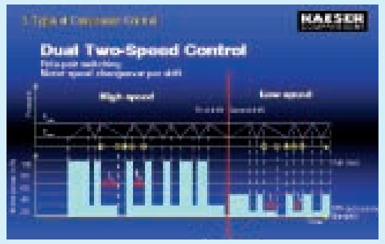
Despite its benefits, compressed air is a relatively expensive energy medium. This means that costs must be saved wherever possible. One of the main causes of increased costs is a mismatch in compressor capacity to fluctuating air demand. Often, compressors are only loaded by a factor of 50 %! A lot of users are not even conscious of this fact because their compressors have an indicator showing hours in operation but not how many of those hours it was under load. Well-matched compressor systems can help by increasing the load factor to 90 %, with power cost savings of up to 20 % or more.

1. Internal control

a) Full load / off-load running
Most compressor packages use three-phase asynchronous drive motors. The permissible switching frequency of these motors becomes less the higher the rating.
This lower frequency does not correspond with the frequency needed to switch compressors with narrower switching differentials off and on as dictated by the actual air demand, so that the compressors are run off-load (idled).
The pressurized end of the compressor is unloaded but the motor still runs for the off-load period. The power consumption of a compressor switched to off-load running is still 20 % of the power needed under full load and must be regarded as a loss.

b) Variable Speed drive
The efficiency of variable speed compressors controlled by a frequency inverter is not constant over their complete control range. In the range between 30 % and 100 %, efficiency reduces from 94 % to 86 % for a 90 kW motor for example. Added to this are losses in the frequency inverter and the non-linear performance

characteristic of the compressors. If variable speed compressors are wrongly used, they can turn into power-eaters without the user being aware of the fact. This means that variable speed drive is not a universal remedy in the search for maximum efficiency and



power-saving compressor operation.

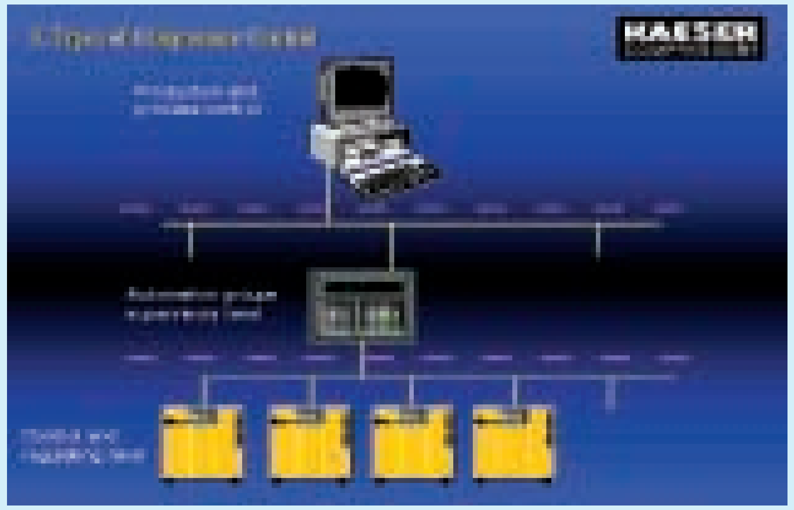
2. Classification of the air demand
Generally, compressors can be classified into base load, medium load, peak load or standby units according to their function.

a) Base load air demand
Base load air demand is the volume of air constantly needed by a factory.

b) Peak load air demand
In contrast, the peak load air demand is the volume of air demanded at certain peak load times. It varies in volume because of the demand from differing consumers. To fulfill the diverse load functions as well as possible, compressors must be fitted with different controllers. These slave controllers must be capable of upholding compressor operation and thus the supply of compressed air should a defect occur on the master controller.

3. Master controllers
Master controllers coordinate the operation of compressors in an air supply system by switching the individual machine on or off according to the air demand.

a) System splitting
Splitting is the division of compressors of equal or of differing rating and type of control according



to base load and peak load air demand.

b) The tasks of a master controller
Coordination of compressor operation is a demanding and comprehensive task. Modern master controllers must not only be able to put compressors of differing make and size into operation at the right time, they must also be capable of monitoring the system for maintenance purposes, balancing the operating hours of the machines and recording malfunctions to bring down servicing costs and increase reliability

c) Correct grading
An important condition for an efficient – that means energy saving – master controller is perfect grading of the compressors. This means that the control range of the peak load compressor must overlap the next base load compressor to be selected. The control range of a variable speed compressor used to handle peak loads must be greater than the maximum delivery of the next compressor to be sequenced. Otherwise the efficiency of the air supplies cannot be guaranteed.

d) Intrinsically safe data transfer
Another significant condition for perfect function and efficiency of a master controller is safe data transfer. It must be ensured that messages can not only be transferred between the individual compressor units and between the compressors and the master controller but also to the central control system as well. In addition, the routes must be monitored so that faults, such as lack of continuity in a connecting cable are immediately recognized

Normal transfer methods:
1. Volt-free contacts
2. Analog signals of 4 – 20 mA
3. Electronic interfaces such as RS 232 or RS 485

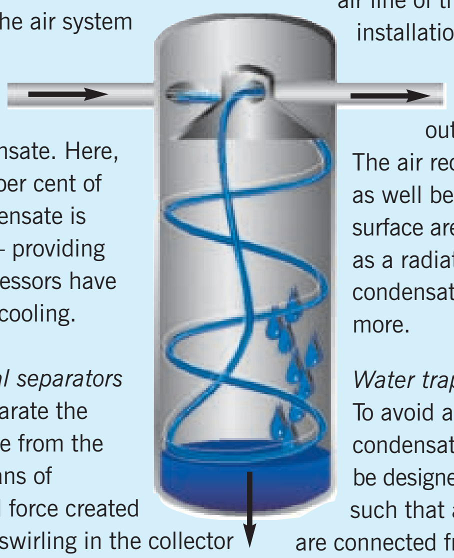
The most modern method of transfer is the Profibus which can pass large volumes of data in the shortest time over long distances without problem. This means that master control systems must no longer be located within the air supply system itself.

4. Condensate and its correct, efficient drainage

Condensate is both an undesirable and unavoidable byproduct of compressed air production. We have already discussed how it is formed in chapter 2. We explained how a 30 kW compressor with a capacity of 5 m³/min produces 20 liters of condensate per shift. This liquid must be removed from the air system to avoid malfunctions, production downtime and corrosion. In this chapter we explain how you can drain condensate correctly and save significant costs at the same time.

1. Condensate drainage
As you can see in the illustration above, condensate, contaminated by diverse pollutants, collects at certain points in every air system. Reliable condensate drainage is thus imperative to ensure quality air, operational reliability and the efficiency of the compressor system.

a) Collection and drainage points
Initially, mechanical elements of the air system serve to collect and drain the condensate. Here, 70 to 80 per cent of total condensate is collected – providing the compressors have good aftercooling.



Centrifugal separators
These separate the condensate from the air by means of centrifugal force created by the air swirling in the collector tank. To function optimally, each compressor must have its own centrifugal separator (illustration right).

Intercoolers
On two-stage compressors with intercoolers, condensate collects at the separator of the intercooler.

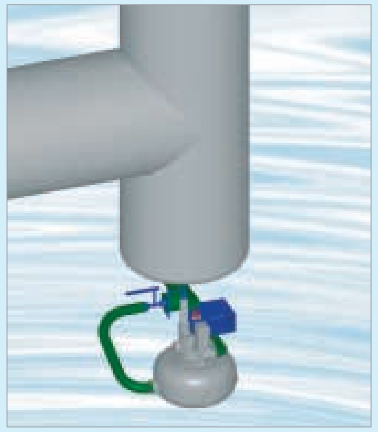
Air receivers
As well as its main function as a storage or buffer tank, the air receiver also separates condensate from the air by gravity. When of sufficient size (compressor capacity per min ÷ 3 = air receiver size in m³), it is just as effective as a centrifugal separator, but in contrast it can be used in the main air line of the compressor installation, providing the air inlet is at the bottom and the outlet is at the top. The air receiver cools the air as well because its large surface area functions as a radiator, improving condensate separation even more.

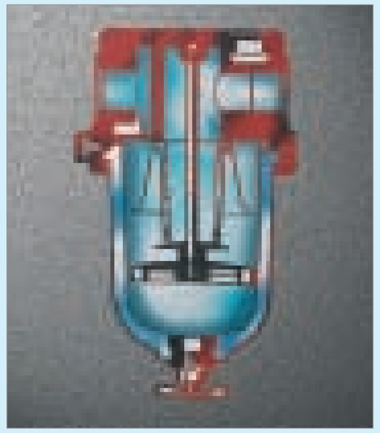
Water traps in the air line
To avoid an undefined flow of condensate, the air line must be designed in the wet area such that all inlets and outlets are connected from above or from the side. Defined condensate outlets leading downwards, so-called water traps, allow condensate to be removed from the main air line (illustration left, opposite page). With correct design and an air flow of 2 to 3 m/s, a water trap in the wet area separates condensate just as effectively as an air receiver.

b) Air dryers
As well as those already mentioned there are other collecting and drainage points on air dryers.

Refrigeration dryers
Condensate is separated in refrigeration dryers during the cooling and drying process.

Desiccant dryers
Because of the cooling effect in the air line, condensate is already precipitated in the prefilter of the desiccant dryer. In the desiccant dryer itself, water appears only as vapour because of partial pressure conditions.





c) Local separator
If no central air drying system exists, large volumes of condensate collect at the local separators fitted just upstream of the air consumers. However, their servicing needs are very high (center illustration).

2. Commonly used drainage systems
In the main, three systems are used:

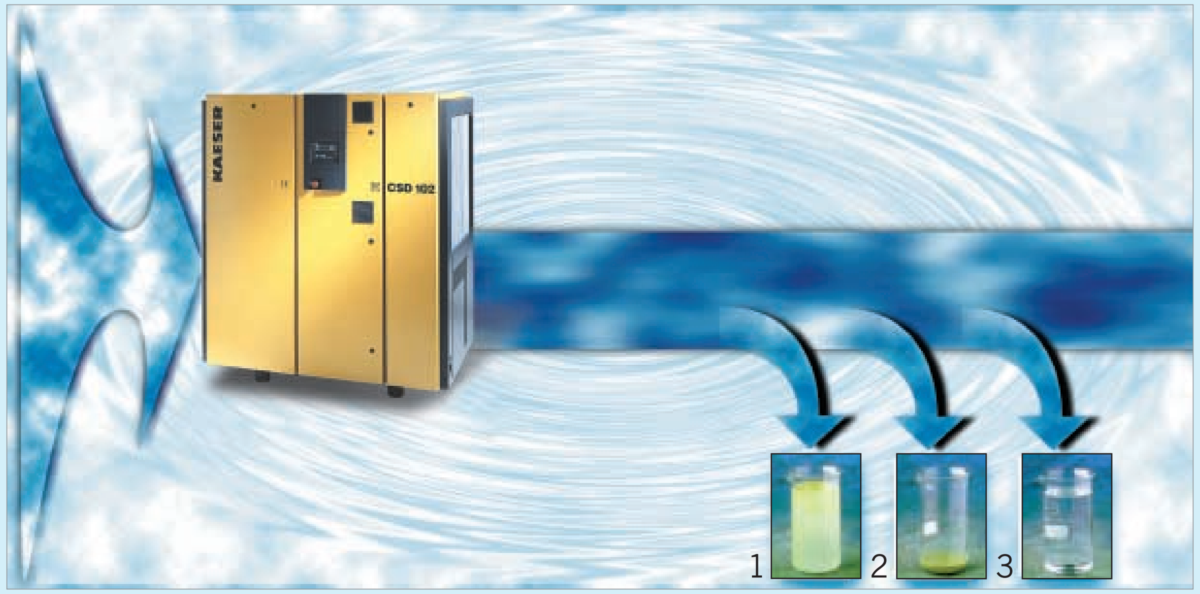
a) Float drains
The float-type drain is one of the oldest drainage systems and replaced the inefficient and unreliable manual drains. However, float drains need intensive maintenance and are often susceptible to malfunction caused by dirt in the condensate.

b) Solenoid valves
Time controlled solenoid valves are more reliable than float drains but they must also be checked regularly for clogging and contamination. Wrongly adjusted opening periods can cause air losses and increased consumption of energy.

c) Condensate drains with level control (ECO-DRAIN)
Nowadays, drains using intelligent level control are preferred (right circled). They have the advantage that the float, which is highly susceptible to faults, is replaced by an electronic sensor. This means that in contrast to float drains, faults caused by dirt or mechanical wear are eliminated. Also, air losses (such as occur with float valves) are prevented by the automatically controlled opening periods of the valve. Further benefits are automatic self-monitoring and the possibility of passing on signals to a central control system.

d) Correct installation
A short length of pipe containing a shut-off valve should be fitted between the condensate separating system and the condensate drain. This allows the drain to be isolated during maintenance and the compressed air system can remain in operation.

5. Economical treatment of condensate



Every compressor draws in water vapour and pollutants together with atmospheric air. The condensate resulting from compression must be freed of oil and other contaminants (2), before it can be disposed of as clean water (3)

Condensate is an undesirable byproduct of air compression (see parts 2 and 4). The term 'condensate' is misleading because it could be misunderstood to mean only condensed water vapour. In fact, every compressor acts like an oversized vacuum cleaner, drawing in polluted atmospheric air and passing on these concentrated pollutants with the untreated compressed air!

1. Why do we need condensate treatment?

Users who dispose of condensate by simply pouring it down the drain are risking heavy fines. This is because condensate accumulating during the production of compressed air is a highly dangerous mixture. As well as solid particles, it contains hydrocarbons, sulfur dioxide, copper, lead, iron and other substances caused by growing environmental pollution. The directive for condensate disposal in Germany, for example, is the Water Management Act. This act stipulates that polluted water must be treated according to 'generally approved engineering regulations'. This affects all types of condensate , including condensate from oil-free compressors. There are legal limits for all pollutants and for pH-values. The maximum permissible limit for carbohydrates is 20 mg/l, for example, and the pH limit for disposable condensate ranges from 6 to 9.

2. The composition of condensate

a) Dispersion

Condensate can exhibit various compositions. Generally, dispersion occurs in fluid-cooled screw compressors that are run with synthetic coolants such as Kaeser Sigma Fluid Plus. This condensate normally has a pH value between 6 and 9 and can be regarded as pH neutral. With this kind of condensate, pollutants drawn in from the atmosphere form a coolant layer floating on the surface that is easily separated from the water.

b) Emulsion

A visible sign of emulsion is a milky fluid that does not separate even after several days (see 1 in illustration above). This composition often occurs in reciprocating, screw and sliding vane compressors that are run with conventional oils. In such cases, pollutants are bonded to the components of the oil. Because of the strong, stable mixture, oil, water and pollutants such as dust and heavy metals cannot be separated by gravity.

If the oils contain ester compounds, the condensate could be aggressive and must be neutralized. Treatment of such condensate is only possible with emulsion splitting units.

c) Condensate from oil-free compressors

Because of increasing atmospheric pollution, condensate from oil-free compressors still contains a considerable proportion of oil components. Such condensate often exhibits high proportions of sulfur dioxide, heavy metals and/or other solid particles. This condensate is generally aggressive, having a pH value between 3 and 6, and cannot be disposed of as wastewater, although this is often claimed.

3. External disposal

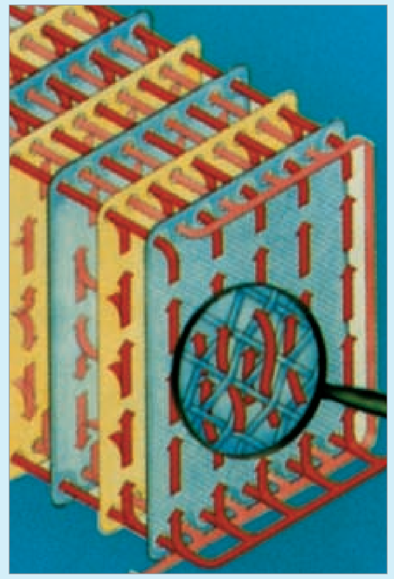
Of course, it is possible to collect the condensate and have it disposed of by a specialized company. However, these costs are between €38 and €150 per cubic meter depending on the composition of the condensate. In view of the amount of condensate accumulating, treatment would be the more economical method. It has the advantage that only about 0.25 percent of the original volume is left over that has to be disposed of to environmental regulations.

4. Treatment processes

a) Dispersions

A triple-chamber separator comprising two initial separating chambers and an activated carbon filter chamber is generally sufficient for this type of condensate. The actual separation takes place through gravity. The oil layer floating on the surface of the fluid in the separating chamber is skimmed off into a canister and disposed of as waste oil. The remaining water is then filtered in two stages and can be disposed of as wastewater. This process saves up to 95 percent of the costs involved if a specialized company disposes of the condensate. Such separators can be supplied with the capacity to handle a compressed air delivery of up to 160 m³/min. If needed, several separators can be connected in parallel.

Gravitational separators such as this Aquamat treat condensate dispersion reliably and economically



Membrane separators are mostly used for stable condensate emulsions

b) Emulsions

In general, two types of separator are used for the treatment of stable emulsions. Membrane separating systems work on the principle of ultra-filtration using the so-called cross-flow process. During this process, pre-filtered condensate permeates the membrane and leaves the separator as clean water that can be disposed of as wastewater, the process repeating itself. The second type uses a powdered splitting agent which encapsulates oil particles, forming easily filtered macro-flakes. Filters of a defined pore size reliably retain these flakes. The drained water can be disposed of as wastewater.

c) Condensate for oil-free compressors

Condensate from oil-free compressors must be treated with chemical separating processes. This includes pH neutralization through addition of alkaline and the binding and concentration of heavy metallic components in a filter cake which has to be disposed of as hazardous waste. This process is by far the most complex. Special disposal approval must be obtained that covers not just possible oil components in the condensate but also concentrated pollutants drawn in from the ambient air. The latter contaminate the condensate considerably.

6. Efficient treatment of compressed air

Experts have been arguing for years on the subject of the most efficient method of treating compressed air. The core question is, which is the most cost-effective compressor system that can produce oil-free compressed air? Leaving aside the statements of individual manufacturers, there is no doubt that today, high grade, oil-free compressed air quality can be achieved both with oil-free (dry) compressors and with oil or fluid-cooled compressors. This means that the only criteria deciding system choice is its cost-effectiveness.

1. What is „oil free air"?
According to ISO 8573-1, compressed air can be described as oil free if its oil content (including oil vapours) is less than 0.01 mg/m³. That is approximately four hundredths of that in atmospheric air. This quantity is so small that it can hardly be detected. But what about the quality of the compressor's intake air? This is obviously highly dependent on environmental conditions. Even in normally contaminated zones the hydrocarbons in the air caused by industry and traffic emissions can lie between 4 and 14 mg/m³. In industrial areas, where oil is used as a lubricating, cooling and processing medium, the mineral oil content alone can be way above 10 mg/m³ plus hydro-carbons, sulphur dioxide, soot, metals and dust.

2. Why treat air?
Every compressor, regardless of type, sucks in contaminated air, concentrates it by compression and passes it on to the main air network if no treatment measures are taken.

a) Air quality in oil-free compressors
This especially applies to dry running compressors. Because of the contamination mentioned above it is impossible to generate oil-free compressed air with a compressor that is only provided with a three-micron dust filter. Dry running compressors do not have any further treatment components other than these dust filters.

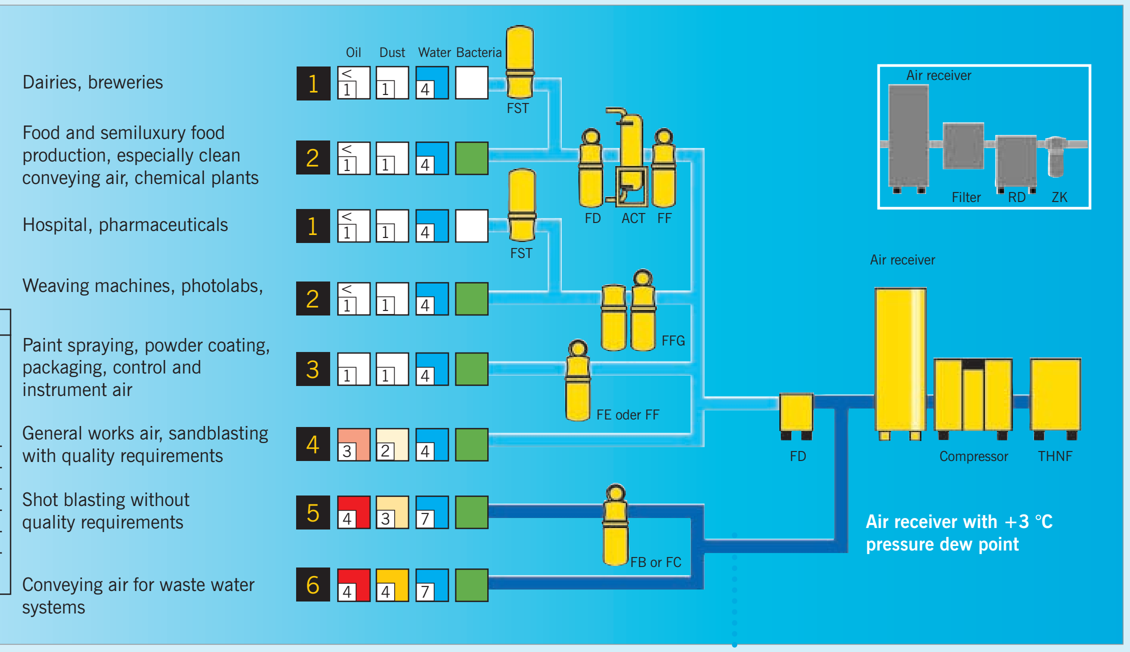
b) Air quality in fluid/oil-cooled compressors
In oil and fluid-cooled compressors aggressive matter is neutralised and solid matter is partly washed out of the air by the coolant, but without treatment, there is still no possibility of getting oil-free air.
Neither oil-free nor oil-cooled compression alone can provide air that is classified as oil-free quality to ISO 8573-1.

c) Compressed air drying
Before the compressed air is supplied to the user it must be dried sufficiently. In most cases, refrigeration drying, is used, as this is the most efficient.

3. Selection of the right compressor system
The selection of a compressor to suit a particular application should not be made with a view to the air quality achieved by the individual compressor alone but rather in relation to the overall cost of the compressor and treatment eqipment needed to achieve the desired air quality. This should also take into account the cost of energy and servicing that can be up to 90 percent of the overall cost of air production. The lion's share of 75-85 percent is the cost of energy. In the lower pressure range of 500 mbar to around 3 bar, oil-free systems such as rotary blowers (up to 2 bar(a)) are very cost-effective. Between 4 bar(a) and 16 bar(a), fluid or oil-cooled screw compressors, in contrast, are significantly superior to the so-called 'oil-free' compressors as far as efficiency is concerned. Above 5 bar(a), 'oil-free' compressors must be designed with two compression stages to achieve a reasonable relation between power requirement and air delivery. The large number of coolers needed, the high speeds, design problems, water-cooling and high procurement costs bring into question the advisability of using oil-free compressors within this pressure range. An added disadvantage is that the air from 'oil-free' compressors retains sulphur components drawn in with atmospheric air which, when precipitated as condensate, is aggressive with a pH value between 3 and 6.

4. Treatment with the KAESER Pure Air System
Modern fluid or oil-cooled compressors have a 10 percent higher degree of efficiency than compressors using oil-free compression. The Pure Air System developed by KAESER for fluid or oil-cooled screw compressors provides further cost-savings of up to 30 percent. The oil carry-over achieved by this system is below 0.003 mg/m³, far below the limits laid down in the ISO standard. The system includes all the treatment components needed for achieving the required air quality. Depending on the application, either refrigeration or desiccant dryers are used (see also chapter 2, page 7) together with various filter combinations. Quality ranges from dry air through particle-free up to oil-free and sterile compressed air, all reliably and cost-effectively achieved to the quality classes laid down in the ISO standard.

5. Treatment flow chart
A treatment flow chart is now included in every new Kaeser screw compressor brochure. The correct combination of equipment for any application can be determined at a glance.



ISO 8573-1					
Class	Solids mg/m³	Solids µm	Water mg/m³	Water DTP °C	Oil g/m³
1	0.01	0.1	0.1	–70	0.003
2	0.1	1	1	–40	0.117
3	1	5	5	–20	0.88
4	5	15	8	+3	5.95
5	25	40	10	+7	7.73
6	–	–	–	+10	9.36
7	–	–	–	not specifiable	

To use the flow chart (with refrigeration dryer):
find your application (first column on the left), read off the degree of purity (second column), columns 3 to 6 are colour-coded according to contamination.
You can read off the treatment components required on the right-hand side

Explanation:

THNF = bag filter
cleans dusty and highly contaminated intake air

ZK = centrifugal separator
separates accumulating condensate

FB = prefilter 3 µm
separates liquid droplets and solid particles >3 µm, oil content ≤5 mg/m³

FC = prefilter 1 µm
separates liquid droplets and solid particles >1 µm, oil content ≤1 mg/m³

FD = particulate filter 1 µm
separates dust particles (attrition) >1 µm

FE = mikrofilter 0,01 ppm
separates aerosol oil and solid particles >0,01 µm, aerosol oil content ≤0,01 mg/m³

FF = mikrofilter 0,001 ppm
separates aerosol oil and solid particles >0,01 µ m, aerosol oil content ≤0,001 mg/m³

FG = activated carbon filter
for adsorption of oil vapours, oil vapour content ≤0,003 mg/m³

FFG = combination filter
comprising FF and FG

RD = refrigeration dryer
dries compressed air, pressure dew point to +3 °C

DD = desiccant dryer
dries compressed air, DC series: heatless regeneration, pressure dew point to -70 °C; DW, DN, DTL, DTW series: heat regeneration, pressure dew point to -40 °C

ACT = activated carbon adsorber
for adsorption of oil vapours, oil vapour content ≤0,003 mg/m³

FST = sterile filter
provides bacteria-free compressed air

Foreign matter:

- oil
- dust
- water/condensate
- bacteria

Degree of filtration

1 Oil vapour < 0,003 mg/m³, retention of particles > 0,01 µm, sterile, free of odours and flavor

2 Oil vapour < 0,003 mg/m³, retention of particles > 0,01 µm

3 Oil vapour < 0,01 mg/m³, retention of particles > 0,01 µm

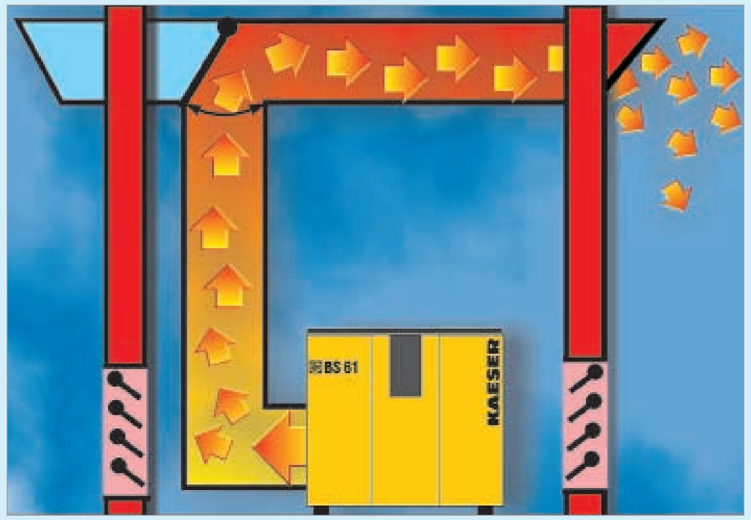
4 Aerosol oil < 1 mg/m³, retention of particles > 1 µm

5 Aerosol oil < 5 mg/m³, retention of particles > 3 µm

6 Untreated

7. Energy and cost savings by heat recovery

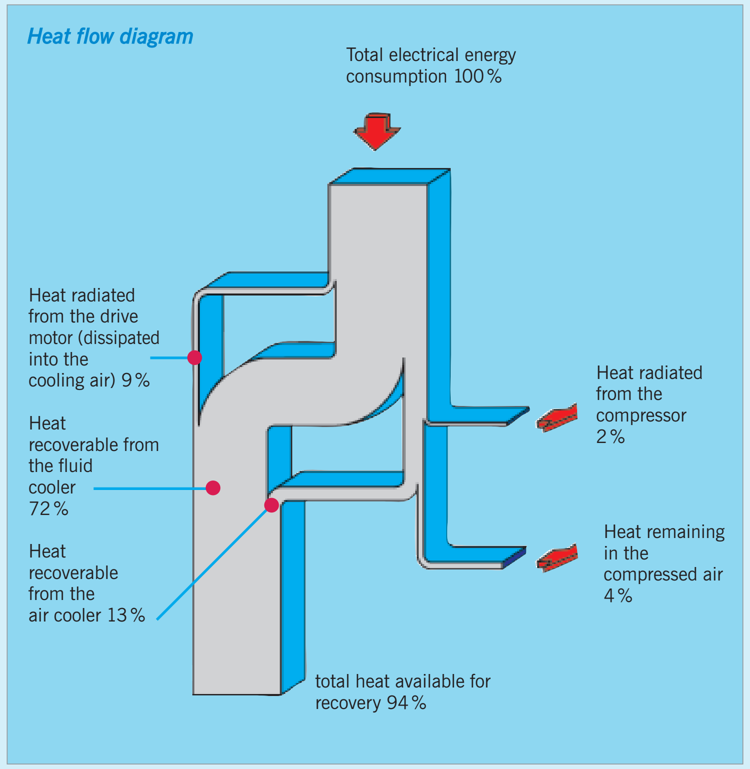
These days, energy saving is not only a sound economic measure but also an ecological necessity. Compressor manufacturers offer many possibilities such as recovering waste heat from rotary screw compressors.



Heat recovery system with ducting and control flap to direct the flow of heated cooling air.

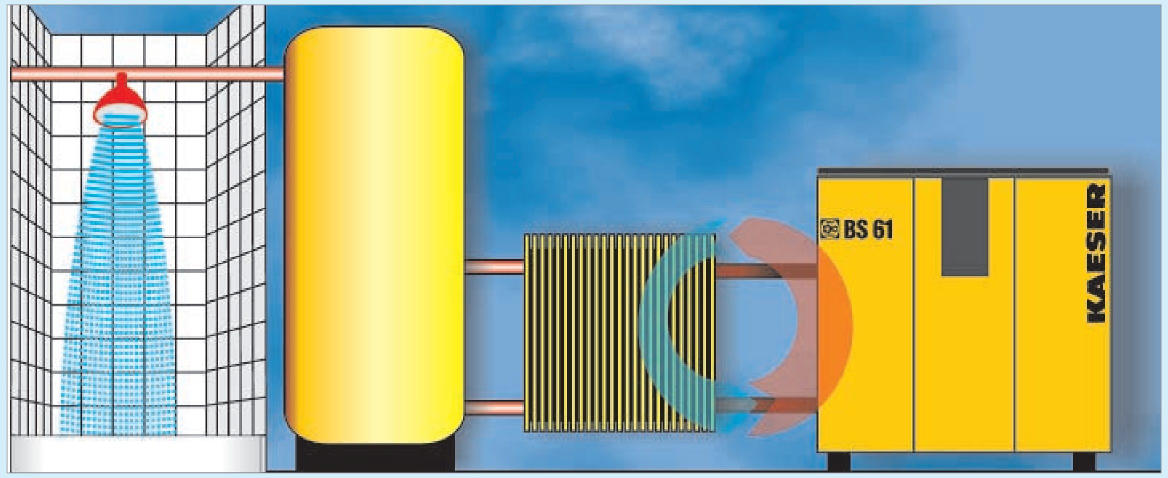
1. Compressors primarily generate heat
Although this statement may seem unbelievable, the truth is that almost 100% of the electrical energy input of a compressor is turned into heat! The action of compression gives the air energy potential which is given up at the point of use by the compressed air expanding and drawing heat from the environment.

2. Up to 94 percent useable energy
The major proportion of the energy recoverable as heat, about 72 %, is transferred into the compressor cooling fluid and about 13 % into the compressed air itself. Up to 9 % is given out by the drive motor into the cooling air and in a fully encapsulated screw compressor this is also recoverable to bring the total portion of input energy recoverable as heat up to a startling 94 %!



Of the remaining energy, 2 % is radiated away from the compressor package and 4 % remains in the compressed air (see heat flow diagram).

3. Possibilities of heat recovery
Users wanting to improve the economy of their compressed air generating plant can chose from a number of heat recovery possibilities.



Heat recovery system using a plate-type heat exchanger to heat water to 70 °C

a) Air heating
The simplest and most direct method of recove-ring the heat generated in a fluid cooled screw compressor is by means of the cooling air used to carry away the heat from the compressor unit, fluid cooler, motor etc. This heated air is ducted away to be used for space heating of warehouse or workshop, and applications such as drying, heat curtains and pre-heating of combustion air.
When the heated air is not needed a manual or automatic flap or louver discharges it outside the building. This can be thermostatically regulated to maintain a constant, temperature. This method allows utilisation of 94% of the electrical energy consumption of a screw compressor and is well worth it, even in small units, as an 18.5 kW compressor can make easily enough energy available to heat a normal family dwelling.

b) Water heating
Heat can be recovered from either an air cooled or a water cooled compressor package by means of a heat exchanger installed in the airend cooling fluid circuit. These may be of the plate-type or fail-safe type depending on use to which the hot water is to be put: for heating or washing or for a production or cleaning process. They can achieve water temperatures up to 70 °C.

With correct planning, heat recovery systems for compressor packages upwards of 18.5 kW capacity can be amortised within two years.

4. Reliability consideration
A heat exchanger to recover heat from the airend cooling fluid of a water-cooled compressor should not be arranged as the primary method of compressor cooling. Rather, it should be installed as an auxiliary cooler so that in the event of it failing, or if no hot water is needed, the compressor can revert to its primary air or water cooling system and so continue, delivering compressed air.

5. Conclusion
Recovering the heat of compression for a useful purpose is an intelligent and considerate way of improving the economics of compressed air production and relieving stress on the environment at the same time. The effort involved is relatively small in proportion to the benefit and the investment quickly recovered, depending on the local conditions, the purpose to which the heat is put and the method of heat recovery chosen

8. Preventing energy wastage (1)

Points to note during planning and installation of a compressed air main.

Compressed air, as an energy medium, is extremely flexible but not exactly cheap. To be economical, the three factors of generation, preparation and distribution must be harmoniously planned and executed. As well as the compressed air supply system itself, the distribution network, or air main, must be properly dimensioned and installed.

1. Economical compressed air generation.
When all cost factors of energy, cooling medium, maintenance and equipment devaluation are taken into account, then the cost of each cubic meter of air produced, depending on the compressor size, utilisation, condition and model, is between 0.5 and 2.5 Euro cents. Many production facilities place great importance on economical compressed air generation, which is why they choose a liquid-cooled rotary screw compressor in the first place as these types offer 20 % cost savings over other types of compressor.

2. Air treatment influences the air main.
Rather less consideration is given, on the other hand, to appropriate air treatment, which is regrettable as only by proper air treatment can low maintenance costs be expected for air consumers, pipework, etc.

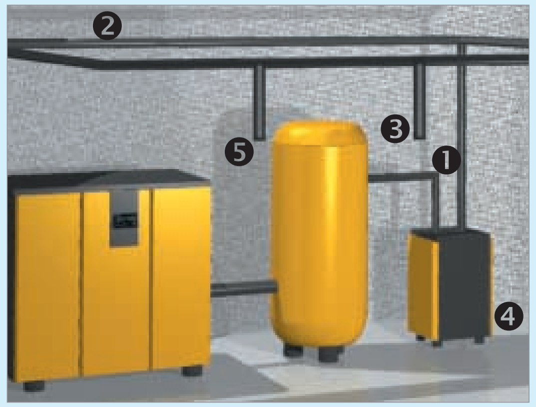
a) Refrigeration dryers reduce maintenance.
Refrigeration drying is sufficient treatment in 80 percent of all applications and is often preferable to filter drying as a refrigeration dryer consumes only about three percent of the energy that the compressor would otherwise use to make up losses in a filter network. In addition, the saving in costs for maintenance and repair of the air consumers and air main can be easily ten times the average cost of refrigeration drying.

b) Space-saving combinations
For smaller or decentralized applications, space-saving

combinations of screw compressor, refrigeration dryer and air receiver (illustrated), or combinations of rotary screw compressor and drier in tower layout are available.

3. Planning and installing an air main.
First, it must be decided if the compressed air generating plant is to be centralised or not. A centralized system is generally sufficient for small and medium applications as this does not give rise to problems encountered in a greatly extended air main such as high installation costs, frost danger from non-insulated outside lines and high pressure losses due to long pipe runs.

a) Correct dimensioning
A calculation is necessary to establish the correct dimensions of



an air main. This should be based on a maximum acceptable pressure drop of 1 bar between the compressor and the air consumer, including a normal treatment system (refrigeration drying).

Individual pressure losses can be assumed as follows:
(illustration above)

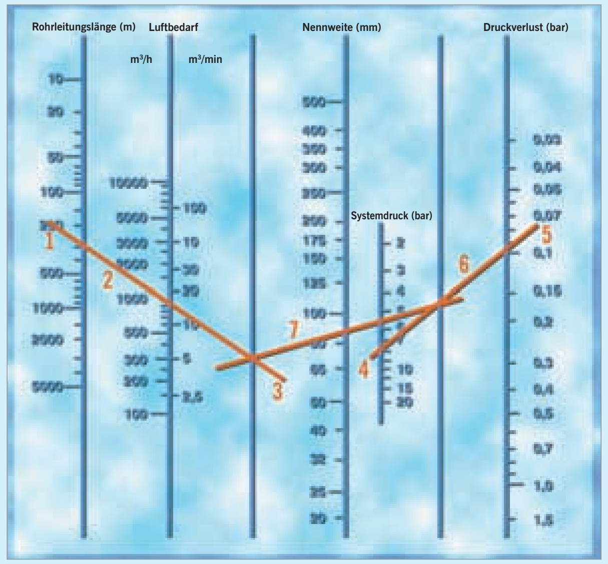
Main supply line (1)	0.03 bar
Distribution lines (2)	0.03 bar
Branch lines (3)	0.04 bar
Dryer (4)	0.20 bar
FRL units and hoses (5)	0.50 bar
Total	**0.80 bar**

This list shows how important it is to compute the pressure drops in the individual line sections. It is not sufficient to consider only the total length of pipework involved but instead the technical flow length must be calculated with joints and valves also taken into consideration. However, one usually has no accurate count of all fittings in the early planning stage and so the technical flow length is estimated by multiplying the total line length by a factor of 1.6. The pipeline diameters are then determined by means of the straight-line graph shown opposite.

b) Energy-saving pipe runs.
In order to save energy the piping layout should be as straight and direct as possible. For instance, one can avoid curves in laying pipework around an obstacle by repositioning the run to lie straight alongside it. Sharp, 90° corners cause high pressure drops and should be replaced with large-radius elbows. Instead of the often-used common water shutoff valves, ball or butterfly valves with full bore throughflow should be used. In wet areas, the compressor room only in the case of modern air supply system, connections to and from the main supply line should be made from above or at least from the side. The main supply line should have a drop of 2 in 1000 and at its lowest point should be provided the possibility of connecting a condensate drain. In dry areas, the pipeline can be horizontal with vertical pipes dropping down to air takeoff points.

c) What pipe material is correct?
No specific recommendation can be given here with regard to the material properties and price alone gives little help in reaching a decision. Zinc-coated steel, copper and plastic pipes are at about the same price level if one adds material and installation costs, and stainless steel about 20% more expensive. However, more efficient processing methods are reducing even this price differential.
Most manufacturers offer tables in which are given the optimal conditions for every pipe material and it is wise to study such tables before making an investment decision. The requirements of the air main in terms of load and stress for the present and the foreseeable future should be listed and taken into consideration.

d) Correct jointing
Each pipe material has its own technique of jointing and it is most important that this be carried out correctly to result in a mechanically sound and leak-proof joint. A rule of thumb is that the more difficult it is to undo a joint, the less it is likely to leak.



9. Preventing energy wastage (2)

Points to consider when refurbishing an existing air main

Every year, literally tons of money is blown away through aging or poorly maintained air mains, letting the valuable energy source escape unused. Here are some useful tips on refurbishing.

1. Basic requirement - dry compressed air
When planning a new air main, mistakes leading to problems in the future can be avoided, but refurbishing an existing air main can be fraught with difficulties. It is also a pointless exercise if the air fed into the air main contains moisture. Before beginning to refurbish it is a first essential to make sure the air is dried at source.

2. What if there is excessive pressure loss in the main?
If the pressure loss in the main is excessive, even after a satisfactory treatment system has been installed, then the cause is probably deposits in the pipes. Dirt carried in the compressed air is deposited on the pipe walls reducing their effective diameter and narrowing the passage through which air flows.

a) Exchanging or blowing out
If the deposits are firmly encrusted there may be no alternative but to replace sections of pipe. However, in most cases it is sufficient to blow out the pipe to remove deposits, followed by thorough drying out before bringing back into service.

b) Installing supplementary lines
A good solution to increase the effective diameter of a spur main is to lay a second parallel pipe connected to it. A supplementary ring main can also be laid (fig. 1). A properly dimensioned supplementary main not only relieves the pressure drop problem but also increases the reliability of the distribution system in general. A further possibility of improving the flow in a ring main is by cross-connecting lines as illustrated in fig. 2.

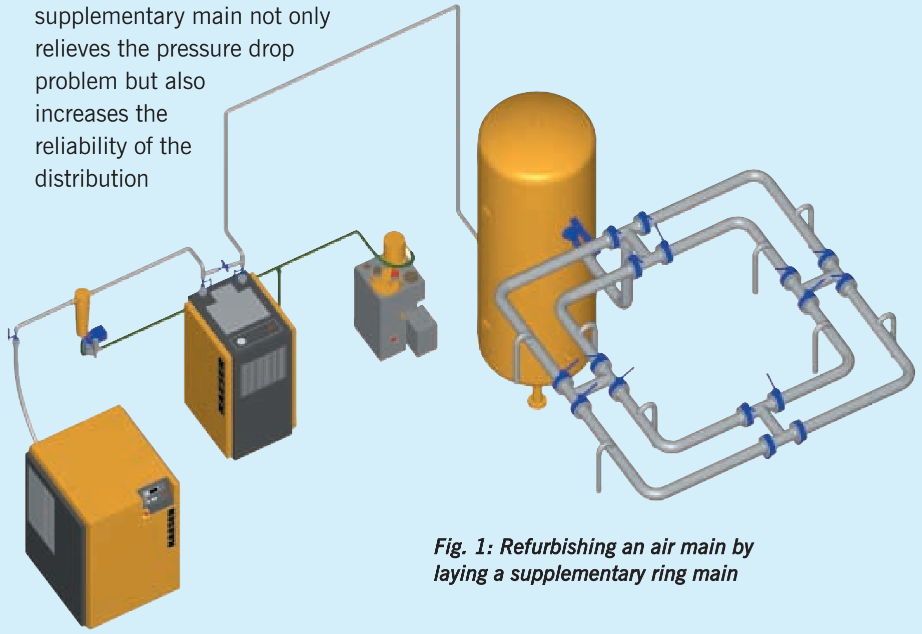


Fig. 1: Refurbishing an air main by laying a supplementary ring main

3. Tracing and stopping leaks
A prime objective of any refurbishment program must be to stop leakage of air.

a) Determining total leakage from an air main
Before searching for individual leaks, however, the overall magnitude of leakage should be established and this is done relatively simply with the help of a compressor and a formula. All air consumers are left connected but switched off and the cut-in times of the compressor measured over a specific period (fig. 3).
The results are then used in the following formula:

$$VL = \frac{VK \times \Sigma t_x}{T}$$

Where:
VL = volume of leakage (m^3/min)
VK = compressor delivery (m^3/min)
$\Sigma t_x = t_1 + t_2 + t_3 + t_4 + t_5$ sum of the time units in which the compressor ran under load (min)
T = total time over which measurements were made (min)

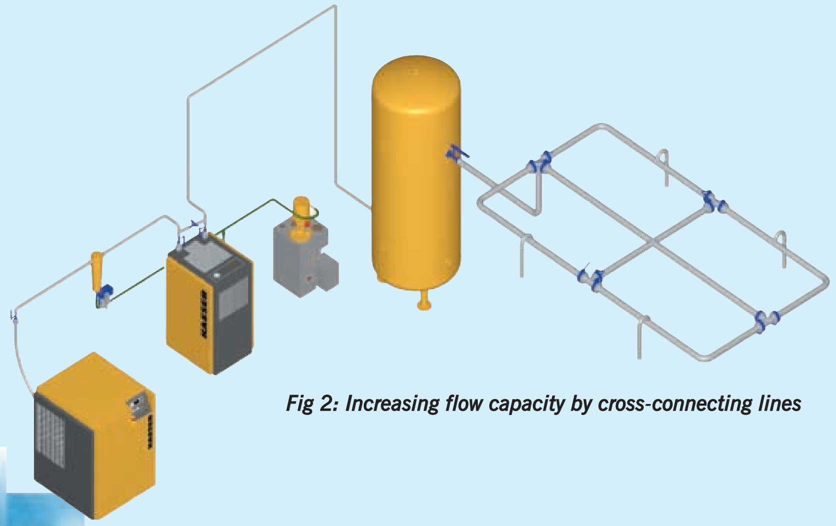


Fig 2: Increasing flow capacity by cross-connecting lines

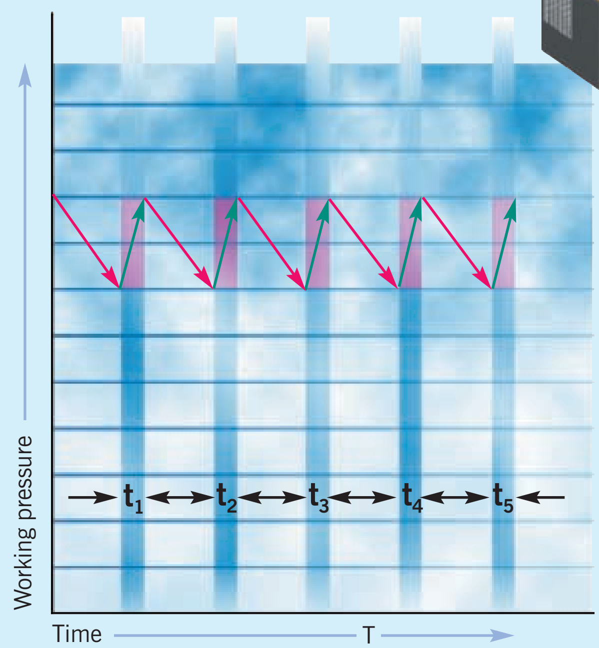
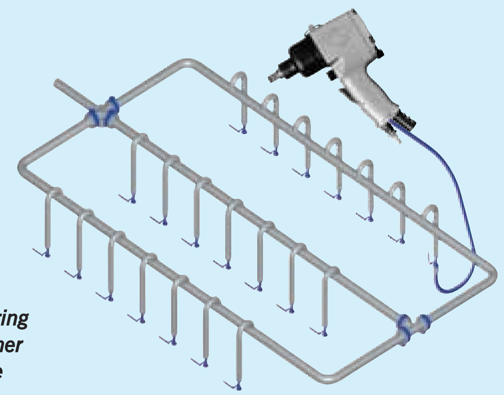


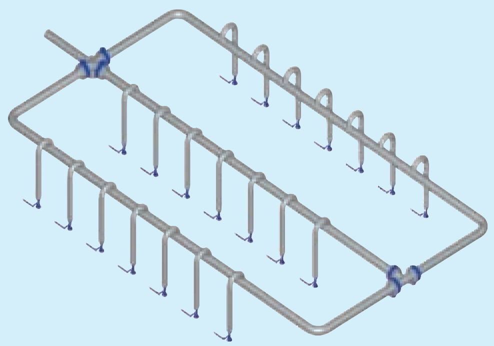
Fig 3: Determining total leakage by measuring cut-in times with supply valves to all consumers open and the consumers themselves switched off

Fig 4



Measuring consumer leakage

Fig 5



b) Measuring consumer leakage
After measurement a) has been made as shown in fig. 4 and the total calculated, the shut off valves upstream of all consumers are closed (fig. 5) and the measurement made again. The difference is then the leakage from the consumers and their fittings.

4. Where are the majority of leaks to be found?
Experience shows that 70% of leaks from an air main occur in the last meter of the line, i.e. at or near the takeoff point. These leaks can usually be easily pinpointed with the help of soap sprays or special sprays.
The main pipework of an air network is generally only a source of significant leakage in the case where old hemp seals, which have been kept damp by moist air begin to dry out when the main is fed by dry air. Such leaks in main pipework are best detected with the aid of ultrasonic instruments.
When the last leak has been located and cured and the effective diameter of the pipeline is sufficient for the flow rate required then the air main is (once more) at its optimum efficiency.

10. Correctly planning air supply systems (1)

Air Demand Analysis (ADA)

Compressed air supply systems are generally complex and can only give their best and most economic performance when properly planned. Kaeser have developed a tool to aid this process, whether it is used for a new installation or the modernization of existing plant. The tool takes the form of a comprehensive service incorporating factors such as compressed air components, customer consultation and the modern techniques of data acquisition and processing.

The spectrum of compressed air applications is extremely broad, from automobile manufacturer to cement works, but the common prerequisite for success is efficient and reliable generation and treatment of the air. The installation must be able to deliver air in the specified quantity and quality at an economic price.

1. Consultation influences efficiency

For an air supply system to be cost effective it must not only suit the application for which it is intended but must also fit the location and the conditions under which it must operate. In other words: the component parts of compressors, treatment plant and pipework must be correctly chosen and dimensioned and be under some efficient means of control. There must be adequate ventilation and a means of dealing with the condensate arising and, if possible, there should be a means of recovering the waste heat generated by the compression process. This is all taken into account in the service offered by Kaeser under the name KESS (Kaeser Energy Saving Service) and includes air demand analysis, planning (fig. 1) realization, operator training and customer service. Of decisive importance are the quality of the consultation and the choice of the right technology. The greatest potential for cost savings lies in power consumption and maintenance rather than in the purchase price itself.

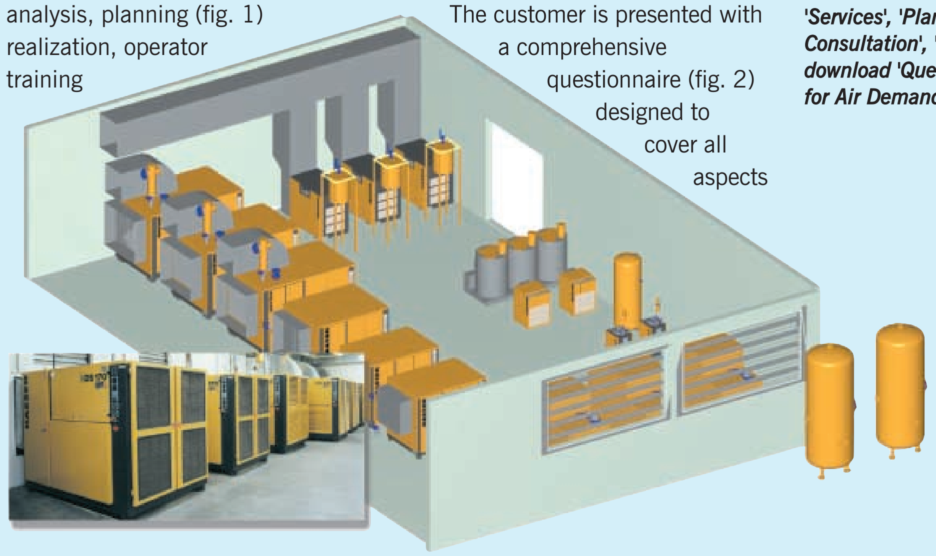


Fig. 1: The facilities of a modern 3-dimensional CAD system allow the air supply system to be designed down to the last detail and laid out to suit user's requirements

2. Air Demand Analysis

The basis of every KESS exercise is an intensive investigation into the user's current and possible future requirements for compressed air. This computer-aided process, developed by Kaeser and given the name ADA (Air Demand Analysis), must take into account the specific circumstances of the application.

a) Planning a new air supply system

The customer is presented with a comprehensive questionnaire (fig. 2) designed to cover all aspects of his anticipated air demand. A Kaeser consultant can then interpret this to select the appropriate hard and software to form a supply system that suits the circumstances in the most economical and environmentally harmonious way.

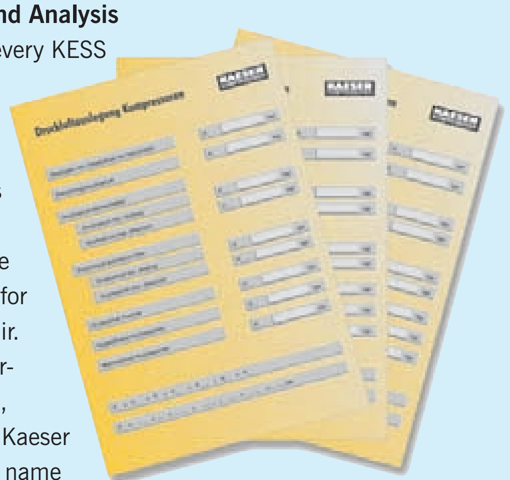


Fig. 2: The special questionnaire used for providing information needed when planning a new air supply system can be downloaded from the Kaeser Website: www.kaeser.com, 'Services', 'Planning and Consultation', 'Analysis', download 'Questionnaire for Air Demand Analysis'.

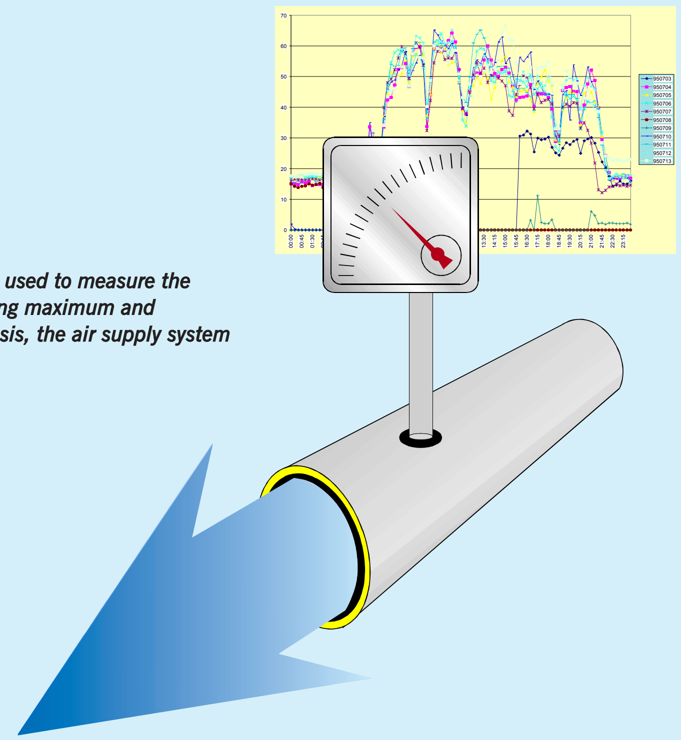


Fig. 3: Measuring instruments and data loggers are used to measure the exact air demand on an existing air system, including maximum and minimum pressures. Using this information as a basis, the air supply system can be optimally redesigned

b) Expanding and modernizing

In contrast to planning new projects, expansion or modernization of existing plant usually provides sufficient reference points for a design that suits requirements. Kaeser can make available measuring instruments and data loggers with which the air demand can be precisely determined in various locations and at different times. It is very important to determine maximum and minimum as well as average values (fig. 3).

c) Testing the efficiency of an existing air supply system

It is recommended to test the efficiency of an existing air system from time to time. This can be done quite easily by means of Kaeser's computer-aided analysis method, which determines whether the compressors are correctly loaded, the control system is optimally programmed and leakage rates are within acceptable tolerances. ADA can also be usefully applied if compressors are to be replaced by new machines. This will avoid possible errors in capacity selection that may lead to inefficient utilization, and assists in the planning of a suitable master control system (fig. 4).

d) Changes in operating conditions

It is well worth consulting a specialist when the conditions under which an air system operates are changed, as often simple changes to the working pressure or treatment methods can be made to suit the new circumstances, thereby achieving cost savings.

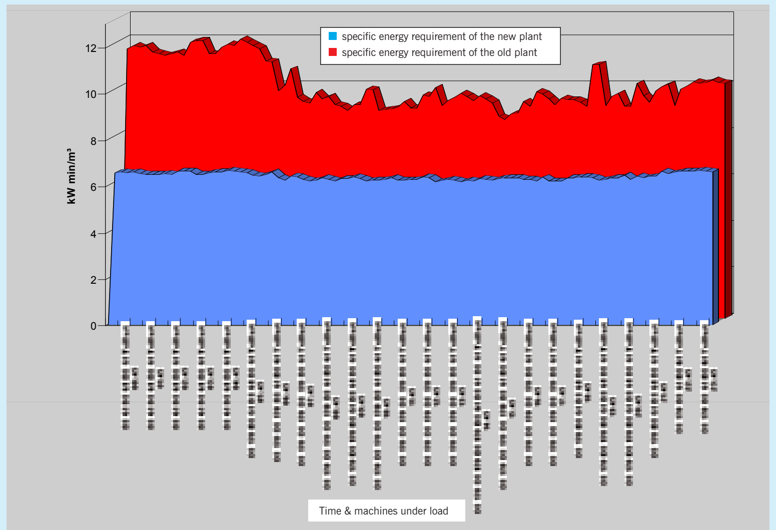


Fig. 4: ADA-acquired data can be graphically presented to show the specific power requirements of the old air supply system (above) and the new (below).

11. Correctly planning air supply systems (2)

Determining the most efficient concept

A lot of compressed air supply systems appear to be bottomless pits as far as expense is concerned but a correctly designed system can be a money saver. The magic formula is 'System Optimisation'. If system optimisation was universally applied, over 30 percent of the average overall compressed air costs incurred in European industrial facilities could be saved. Around 70 to 80 percent of these savings would come from reduction in power consumption. Diminishing fossil fuel resources means that energy will almost certainly become more expensive as years go by - with or without energy taxes. Finding the most efficient concept is vital for the user.

KAESER Energy Saving Service (KESS) includes a computer-aided calculation of system optimisation that makes it easy to choose from several possible alternatives an air supply system most suited to the user's particular application. A design questionnaire, carefully filled out with the help of a KAESER consultant, serves as the basis for the new system selection. This questionnaire takes into account all factors including anticipated overall air consumption and daily fluctuations. For existing air systems the calculation is based on the characteristic daily profile determined by an analysis of the air demand (ADA).

1. Computer-aided findings

Before an existing air supply system can be optimised, all the technical data relating to it and any possible new alternatives are entered into the KESS software. In the shortest possible time KESS then selects the optimum system from the possible alternatives and calculates the related cost savings compared with the others. At the same time, the momentary power consumption at a defined air demand including all losses is calculated and the specific power profile of the air system during the whole of the running period determined (fig. 1). This means that possible weak points in partial load can be detected in advance and remedied. The overall result is a clear statement of potential cost savings and amortisation.

2. It's the mix that counts

For most applications a precisely coordinated combination of compressors of varying size can be established. Generally it consists of large capacity base load and standby compressors combined with smaller peak load machines. The master controller's task is to ensure the best possible balanced specific power to satisfy demand. To do this it must be able to select from up to 16 compressors the most appropriate combination of base load and peak load machines working within a pressure band of only 0.2 bar. Intelligent control systems such as the KAESER 'Vesis' and, more recently, 'Sigma Air Manager' are available that fulfil these high demands. These controllers can be linked with compressors and other components such as condensate drains, dryers, etc. for exchange of data via a bus system. They can also route all data to a control centre via an interface.

3. Structural optimisation

A newly designed or modernised air supply system should make optimum use of the space in which it is to be installed. Modern computer-based design systems such as those that KAESER uses provide worthwhile support in this regard. During the design process they not only use ground plans and P & I flow charts but also computer-generated 3-D representations and animations as well. This means that it is often possible to take advantage of economical air-cooling despite cramped compressor room conditions so that, compared with considerably more complicated water-cooled systems, costs of around 30 to 40 percent can be saved. A further advantage is that possible weak points and sources of faults can be identified and 'designed out' (see fig. 2, a - c).

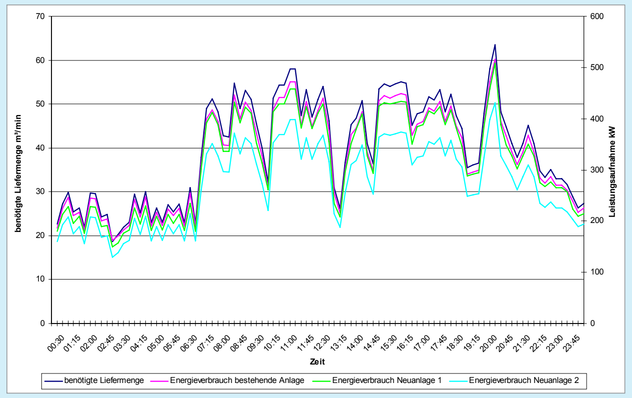


Fig. 1: Comparison of the power consumption of an existing air supply system with new alternative systems over a one-day period related to air demand

4. Operational optimisation and controlling

To ensure economical air supplies over the long term there should not only be an optimised cost-benefit ratio, but also the necessary transparency for effective controlling. The basis for such transparency is the internal compressor controller Sigma Control, an industrial computer with five pre-programmed control modes and the ability to acquire data and transfer it to a data network. At the master controller level a further industrial computer is used, the Sigma Air Manager already mentioned (fig. 3). Its task, as well as appropriate control and monitoring of the air supply system, is to receive all relevant data and pass it on to a computer network (Ethernet). This can take place via Internet or via the Sigma CC software. Together with the visualisation system Sigma Air Control, this PC-installed software can display a list of all the compressors and their most important data to indicate at a glance whether the system is functioning correctly, whether maintenance or alarm messages are activated and how high the system pressure is. The depth of information can be freely selected so that, for example, operational events can be traced, graphs of power consumption, air demand and pressure generated and preventive maintenance scheduled. This modern controlling tool plays a vital part in ensuring uninterrupted supply of compressed air in the required volume and quality - at minimum cost.

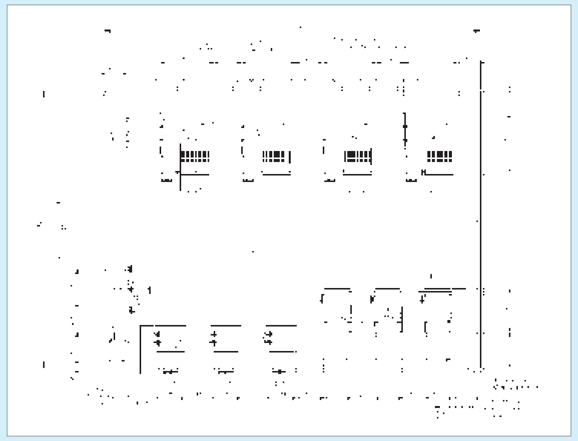


Fig. 2 a: Floor plan of an air supply system in a car manufacturing plant

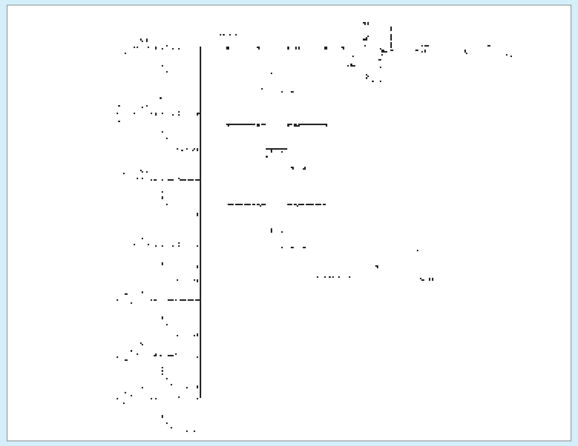


Fig. 2 b: P & I flow chart of the same air system

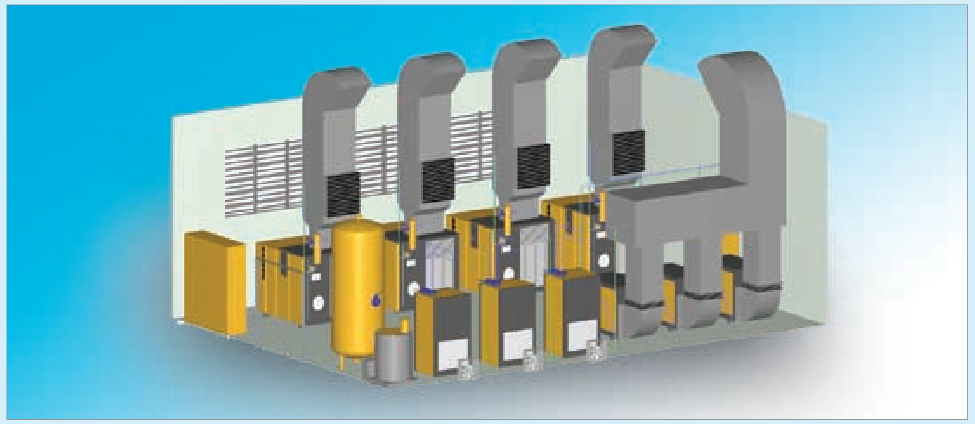
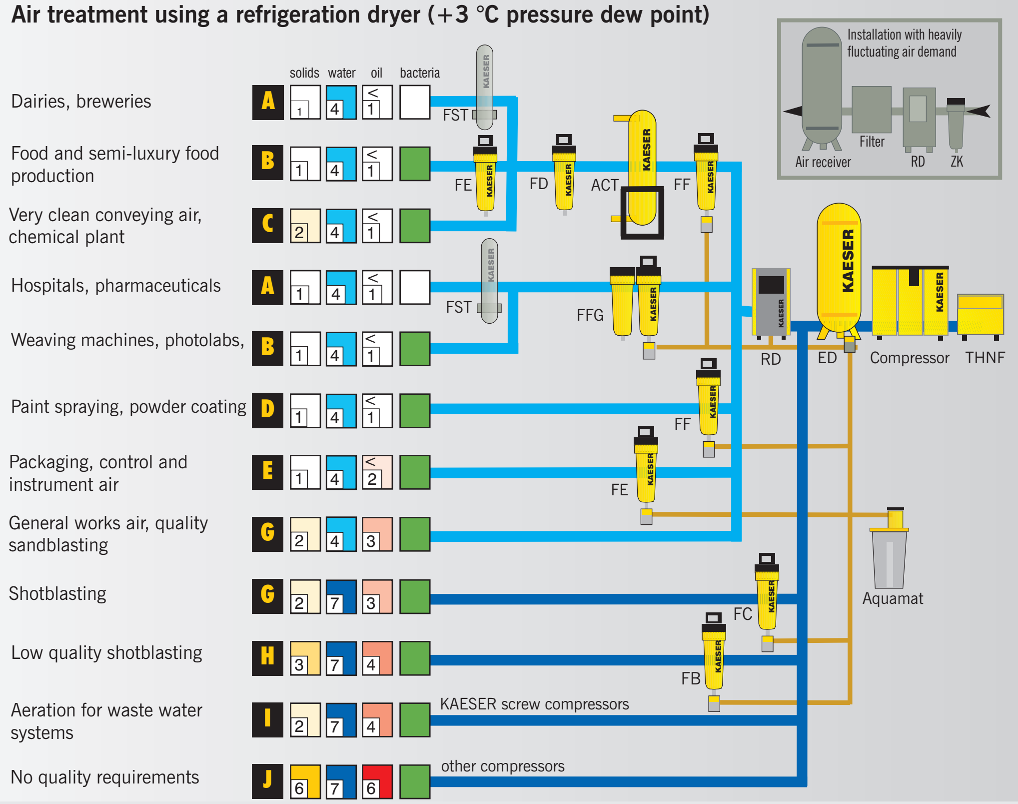


Fig. 2 c: Computer generated 3-D animation allows a virtual stroll through the installation and a view of the equipment from almost every perspective

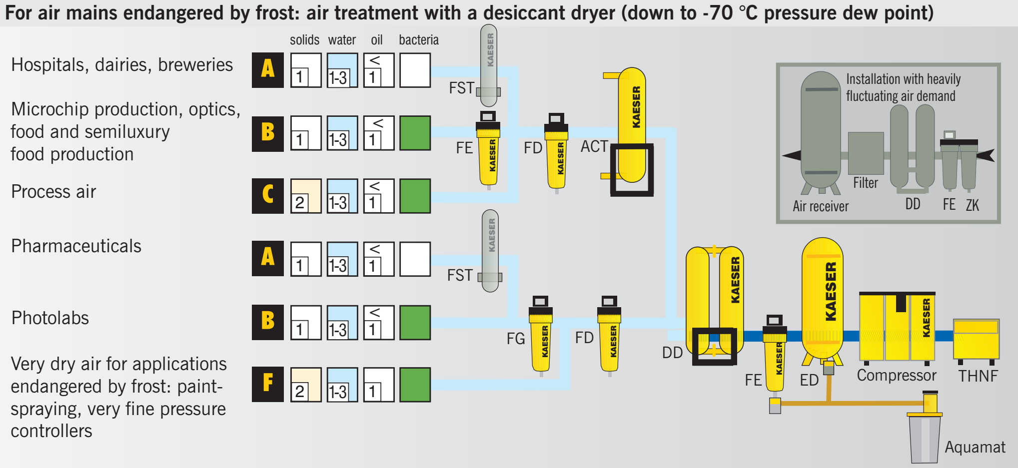
Fig. 3: As well as optimal interplay of all system components, the new Sigma Air Manager master controller ensures significantly increased availability and effective controlling of the compressed air supplies

Choose the required grade of treatment according to your field or application

Air treatment using a refrigeration dryer (+3 °C pressure dew point)



For air mains endangered by frost: air treatment with a desiccant dryer (down to -70 °C pressure dew point)



A Oil vapour content ≤ 0.003 mg/m³, particle retention > 0.01 µm, sterile, odourless and tasteless
B Oil vapour content ≤ 0.003 mg/m³, particle retention > 0.01 µm
C Oil vapour content ≤ 0.003 mg/m³, particle retention > 1 µm
D Aerosol oil ≤ 0.001 mg/m³ particle retention > 0.01 µm
E Aerosol oil ≤ 0.01 mg/m³,particle retention > 0.01 µm
F Aerosol oil ≤ 0.01 mg/m³ particle retention > 1 µm
G Aerosol oil ≤ 1 mg/m³ particle retention > 1 µm
H Aerosol oil ≤ 5 mg/m³ particle retention > 3 µm
I Aerosol oil ≤ 5 mg/m³ particle retention > 1 µm
J Untreated

Explanation:

THNF = bag filter
cleans dusty and highly contaminated intake air

ZK = centrifugal separator
separates accumulating condensate

ED = ECO Drain
electronic level controlled condensate drain

FB = prefilter 3 µm
separates liquid droplets and solid particles > 3 µm, oil content ≤ 5 mg/m³

FC = prefilter 1 µm
separates liquid droplets and solid particles > 1 µm, oil content ≤ 1 mg/m³

FD = particulate filter 1 µm
separates dust particles (attrition) > 1 µm

FE = microfilter 0.01 ppm
separates aerosol oil and solid particles > 0.01 µm, aerosol oil content ≤ 0.01 mg/m³

FF = microfilter 0.001 ppm
separates aerosol oil and solid particles > 0.01 µ m, aerosol oil content ≤ 0.001 mg/m³

FG = activated carbon filter
for adsorption of oil vapours, oil vapour content ≤ 0.003 mg/m³

FFG = combination filter
comprising FF and FG

RD = refrigeration dryer
dries compressed air, pressure dew point to +3 °C

DD = desiccant dryer
dries compressed air, DC series: heatless regeneration, pressure dew point to -70 °C DW, DN, DTL, DTW series: heat regeneration, pressure dew point to -40 °C

ACT = activated carbon adsorber
for adsorption of oil vapours, oil vapour content ≤ 0.003 mg/m³

FST = sterile filter
provides bacteria-free compressed air

Aquamat = for condensate separation

Contaminants:

- + solids -
- + water -
- + oil -
- + bacteria -

Degree of filtration:

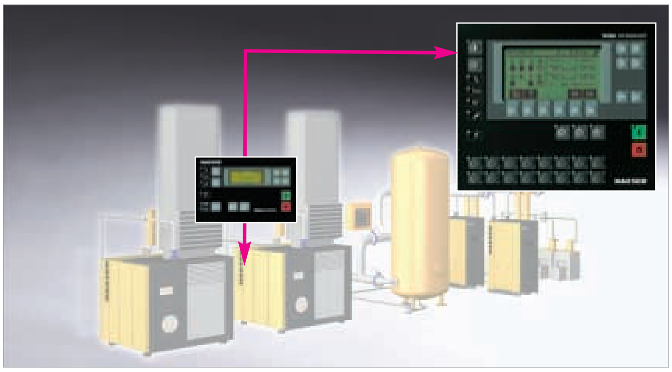
ISO 8573-1					
Class	Solids µm	Solids mg/m³	Water PDP °C	Water g/m³	Oil mg/m³
1	0.1	0.1	-70	0.003	0.01
2	1	1	-40	0.117	0.1
3	5	5	-20	0.88	1
4	15	8	+3	5.95	5
5	40	10	+7	7.73	25
6	—	—	+10	9.36	—
7	—	—	not specifiable		—

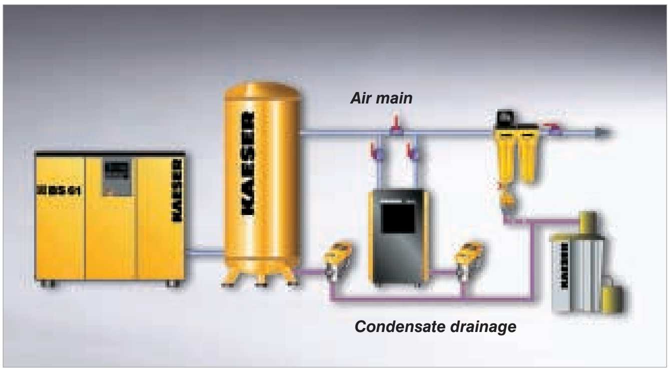
KAESER COMPRESSORS

PRODUCTION RANGE


Rotary screw compressors with SIGMA PROFILE


Refrigeration dryers with SECOTEC energy-saving control


Compressor controllers with Internet technology



Compressed air treatment systems including filters, condensate drains and condensate treatment units, desiccant dryers and activated carbon adsorbers


Rotary blowers with OMEGA PROFILE


Portable construction site compressors with SIGMA PROFILE


Reciprocating compressors for craftsmen and workshops


Compressed air accessories and tools

Editorial

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P-2010ED.1/02 Specifications are subject to change without notice!