WHITE PAPER:

OIL FREE AIR ENSURES RELIABILITY & PRODUCTIVITY

ISO 8573-1 CLASS 0 · SULLAIR COMPRESSORS
OIL FREE

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Why is oil free compressed air of critical importance to industry? The answer is simple – if oil reaches the end product being manufactured, it will cause production down-time and product spoilage – with significant negative financial impacts on the entire facility. This paper will review oil free applications, how to create an oil free specification, how oil gets into the system, and how to establish an ISO 8573.1 Quality Class Zero or One oil free system.

A Hitachi DSP Series Oil Free Rotary Screw Air Compressor

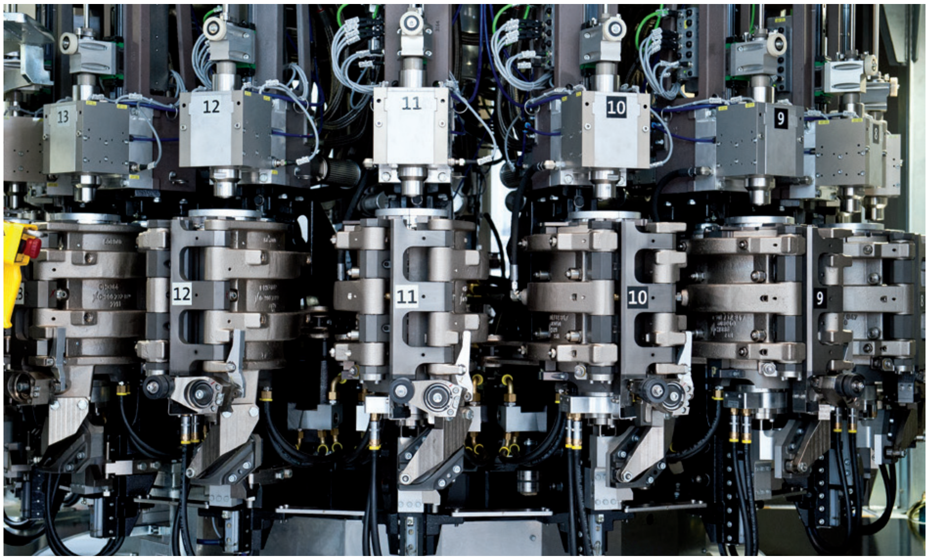
Common Oil Free Applications in Industry
Compressed air is used in most manufacturing and process industries. Most industrial processes have zero tolerance for the introduction of oil into the end product being manufactured. Industries requiring oil free compressed air include plastics, automotive painting, semiconductor, pharmaceutical, food and beverage, as well as many others.

Plastics Industry Oil Free Applications
Injection molding processes use 100 psig compressed air to manufacture plastic containers. These plastic containers are then used to package food products, household chemical products, and a multitude of other product lines. If a plastic margarine tub or a milk bottle has oil-contaminated compressed air introduced into it – the production line must be stopped and all the contaminated containers thrown away.

Stretch blow-molding processes use 350-500 psig oil free compressed air to blow carbonated soft drink and juice bottles. Blow-molding stations, like the Contiform 3 from Krones, produce PET plastic containers with volumes of 0.1 to 3.0 liters. Each machine can have up to 36 blow stations and each blow station can produce 2,250 bottles. A high-speed machine, like the Contiform 3 therefore, can produce up to 81,000 bottles per hour! One clearly sees what one hour of production stoppage will cost a factory in lost revenue and product spoilage.

Most plastic resins, such as PA (Nylon), PC and PET, are hygroscopic materials. They adsorb moisture from humid ambient air and give moisture back to dry air. Every type of resin can hold a specific amount of moisture between its molecular chains. Additional amounts of moisture can be condensed on the surface of the pellets (surface moisture).

Plastic injection molding brings compressed air into contact with consumer good product containers.



Modern stretch blow-molding machines can produce up to 81,000 bottles per hour

Adsorbed moisture in hygroscopic resins and surface moisture in non-hygroscopic resins are known to cause defects in molded plastics and they might lead to a complete production stop. Compressed air plastic resin dryers preheat the material with hot air and then use a small amount of oil free compressed air (that is expanded) to remove the moisture from the resin. The required quality of compressed air, to dry plastic resin, is a 5ºC [41ºF] pressure dew point and virtually oil free compressed air at less than 0.01 ppm oil content.

Motor Vehicle Painting Requires Oil Free Compressed Air
The U.S. Environmental Protection Agency "6H Paint Standard" focuses on controlling air emissions from paint stripping and surface coating operations and came into effect with the compliance deadline of January 10, 2011. This important standard significantly reduces the amount of Volatile Organic Compounds (VOC's) emitted into the ambient air by the automotive manufacturing and collision repair industries. This "6H Standard" has forced the adoption of waterborne paints effectively replacing solvents with water. The SPIES HECKER Permahyd® waterborne base coat is made up of water (70%), solids (20%) and solvent (10%). Compare this to the make-up of a conventional base coat of solvent (84%) and solids (16%). Obviously, there is a lot more water present and this is causing longer flash-off times and affecting through-put in automotive collision and repair shops and in automotive production lines.

Oil free compressed air ensures a perfect paint surface

Oil free and dry compressed air is used to blow paint onto automotive surfaces and to agitate the ambient air during the baking cycle (paint drying) in the paint booth. The presence of moisture or oil, in the compressed air, will create imperfections (fisheyes) in the paint surface and result in product spoilage or "re-do's" creating shop through-put reductions. The introduction of waterborne paints has already caused the baking cycle to be extended, putting pressure on through-put, and there is zero tolerance for any further production delays.

Pharmaceutical blister packaging requires oil free compressed air

Semiconductor and Pharmaceutical Oil Free Applications
The CDA "Clean-Dry-Air" Standard uniformly adopted by the semiconductor and pharmaceutical industries has always specified oil free compressed air and a -40 F (-40 C) to -100 F (-73 C) pressure dew point.

Semiconductor manufacturing is another high-speed, highly-automated process. Production downtime is virtually unheard of because the volume of product manufactured per hour makes the potential revenue losses and product spoilage volumes impossible to live with. Oil free compressed air comes into direct contact with the chips in the semiconductor manufacturing process. Any moisture or oil, present in the compressed air, would destroy the product.

The pharmaceutical industry uses oil free compressed air for bulk conveying and then in the blister packaging process. Compressed air is coming into direct contact with the medicine. Oil contamination would result in FDA violations and potential plant closures.

"Direct-Contact" application using oil free compressed air to blow-off crumbs in a commercial bakery.

Food Industry Oil Free Applications

Compressed air is a key utility supporting the food packaging and food processing industries in North America and is used in a range of pressures from high-pressures up to 750 psi for blow molding and also at lower pressures of 15 psi for blow-off applications.

The production facilities of the different segments within the food industry all have different applications for compressed air.

Powdered food products are transported and packaged using compressed air. With sugars, compressed air is used to bulk transport the product in dense phase and then to put the powder in the bag. In both cases, the oil free compressed air comes into direct contact with the sugar we all eat.

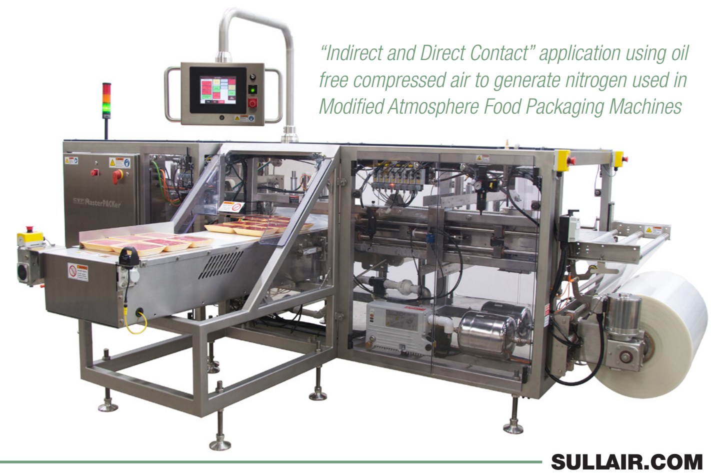
In many fruit and vegetable processing plants, compressed air systems are used for air cleaning of containers prior to product filling, automated product sorting, and product packaging systems. Compressed air often comes into "direct contact" with food products. Vegetable peeling machines use a jet nozzle of oil free compressed air to peel onions and other vegetables. Peeling machines use 90 to 125 psig oil free, dry compressed air.

More "direct-contact" applications include commercial bakeries using oil free compressed air to blow excess crumbs off the bread. Potato chip factories use oil free compressed air in the conveying, sorting and packaging process of the chips.

Food processing machines use compressed air. Food products then come into contact with the machines. This is called "indirect contact" with compressed air. Meat saws use oil free compressed air as do air-driven mechanical food mixers. Canning plants use oil free compressed air to clean the aluminum containers before filling the containers with food. Bottling plants use oil free compressed air to blow water off the bottles after they've been washed.

Nitrogen is used in modified atmosphere packaging (MAP) machines. These are very common in the meat industry. Many plants use on-site oil free compressed air as the feed source to nitrogen generators supplying purity levels up to 99.9999% nitrogen. Pressure swing adsorption (PSA) nitrogen generators use adsorbents that have to be replaced if contaminated by oil. Membrane fiber nitrogen generators are literally destroyed and must be replaced if contaminated by oil. Both situations represent production downtime and replacement costs if oil is present in the compressed air stream.

Another application comes from machines forming, filling and sealing gable-top cartons in the dairy and juice industries. These machines must be washed-down constantly to maintain sanitary conditions. They are not just subjected to water, but are also exposed to chemical cleaners and sodium potassium hydroxide. Pneumatic systems are preferred over hydraulic systems in these machines because in a wet environment, having leaked oil on a polished tile floor becomes a real safety hazard. Low maintenance and downtime associated with pneumatics is also a key reason why compressed air is preferred. This is an example of where compressed air does not come into contact with food – but there is a high risk that it may occur.



"Indirect and Direct Contact" application using oil free compressed air to generate nitrogen used in Modified Atmosphere Food Packaging Machines

Compressed Air Must be Contaminant-Free

Compressed air must be purified of contaminants before use in the food industry. The contaminants are water vapor and moisture, solid particulates (including spores) and oil aerosols and vapors.

The presence of moisture is the primary concern for the food industry because moisture creates the ideal habitat for microorganisms and fungus. Moisture may reside in the piping system near point-of-use applications where compressed air comes into contact with food products. Microorganisms and fungus can grow inside the piping system and then be blown into food products or food containers.

In order to inhibit the growth of microorganisms and fungi, pressure dewpoints must be below -15°F (-26°C). Drying the compressed air to a specified pressure dewpoint is the simple way to eliminate moisture in the compressed air system. The dewpoint specification will be of either +37°F (+3°C) or -40°F (-40°C). In some facilities, both of these specifications may be used to reduce energy costs associated with drying the compressed air – depending upon whether compressed air has any possibility of coming into contact with food products.

Solid particulates must be removed with filtration products from the compressed air system. When compressed air is dried below -15°F (-26°C), harmful microorganisms and fungi are converted into spores. These spores are now a “solid particulate” which must be filtered. Other sources of solid particulates are coatings on the air compressor rotors, pipe-scale from the compressed air piping system, and ambient dust and particulates which may be ingested by the air compressor. It is recommended, when selecting compressed air filtration products, that care is taken to request coalescing filters tested to the new ISO Standard 12500 Parts 1-3.

Oil aerosols and vapors are another significant concern. One myth in compressed air systems is that the use of an oil free air compressor frees the system of any compressed air treatment requirements. This is not the case. Ambient air ingested by air compressors will carry water vapor, particulates, and hydrocarbons and compressed air dryers and filters are always therefore required.

The U.K. Code of Practice for Food Grade Air

The food industry, faced with the question of how to specify a safe and efficient compressed air system, must first define how compressed air is used in their facility. The U.K. Code of Practice for Food Grade Air provides a comprehensive resource on compressed air systems in the food industry. The Code defines three specific types of compressed air systems in the food industry; systems with contact with food, non-contact high-risk, and non-contact low-risk.

THE U.K. CODE OF PRACTICE FOR FOOD GRADE AIR

Contact Recommendation	Dirt (Solid Particulate) Max Number of Particles per m³			Humidity (Water Vapour)	Total Oil (Aerosol + Vapour)	ISO8573.1 Equivalent
	0.1-0.5 micron	0.5 – 1 micron	1-5 micron			
Contact	100,000	1000	10	-40°C PDP	0.01 mg/m³	Class 2.2.1
Non Contact - Low Risk	100,000	1000	10	+3°C PDP	0.01 mg/m³	Class 2.4.1
Non Contact - High Risk	100,000	1000	10	-40°C PDP	0.01 mg/m³	Class 2.2.1

Reference Conditions from ISO8573.1 : Absolute atmospheric pressure 1 bar, Temperature = 20°C. Humidity is measured at air line pressure.

“Contact” means compressed air comes into direct contact with food products. If this is the case, the end user must know that the compressed air must be purified to the “Contact” purity-level as defined in the Code.

“Non-Contact” is defined in the code as, “the process where compressed air is exhausted into the local atmosphere of the food preparation, production, processing, packaging or storage.”

A **“Non-Contact High-Risk”** situation may be where compressed air is used in a blow-molding process to create a package – and then product is introduced into the package later in the day. Many food processors have their own in-house production lines to create their own packaging. Without proper air treatment, it is possible that oil, moisture, and particulates (notably bacteria) could be present on the packaging – waiting for the food product. The U.K. Code of Practice clearly states that “Non-Contact High-Risk” compressed air systems should establish the same compressed air purity specifications as “Contact” systems.

In **“Non-Contact Low-Risk”** systems, The U.K. Code of Practice recommends a +37°F (+3°C) pressure dewpoint. This can be accomplished with refrigerated type compressed air dryers located in the compressor room (centralized air treatment). Each facility will have to determine if further point-of-use air dryers (de-centralized) are required to ensure the dewpoint specification.

How to Create An Oil Free Specification

What does oil free compressed air mean in terms of parts-per-million (ppm) oil content in a compressed air system? How does a plant engineer specify oil free compressed air? The International Standards Organization has issued the ISO 8573.1 Air Quality Classes, for compressed air, permitting engineers to place a clear definition on the air quality they require in their process.

The air quality classes are broken down into six air quality classes of three contaminant types; solids, humidity and liquid water, and oil. Solid particulates (like dust or pipe scale) are removed by filters. Humidity and liquid water is removed by compressed air dryers. Oil (liquid and vapor) is removed by coalescing oil removal filters and activated carbon (charcoal) oil vapor adsorbing filters.

The way an engineer uses this table to communicate required air quality is as follows. "The compressed air system for our food processing plant should meet ISO 8573.1 Air Quality Classes 1.2.1." The first number represents solid particles, the second humidity and liquid water, and the third oil content. This engineer has specified a language and metric neutral compressed air specification for 1 micron solid particles greater than 0.5 and less than 1.0 micron, a -40°F (-40°C) pressure dew point, and oil purity level of ≤ 0.01 mg/m³ (0.008 ppm).

Oil free applications always require Quality Classes "1" or "0" for total oil concentration. Less than 0.01 mg/m³ (Class One) is the most common specification. If a plant wants to specify a lower oil concentration – then the specification is Class Zero. It is important to account for both liquid and vapor when designing the compressed air system. Not only must liquid oil be removed, oil vapors must also be accounted for.

TABLE 1: ISO 8573.1:2001 AIR QUALITY CLASSES [ii]

CLASS	Solid Particles, Particle Size, d (mm)			Humidity and Liquid Water		Oil	
	0.10 < d ≤ 0.5	0.5 < d ≤ 1.0	1.0 < d ≤ 5.0	Pressure Dew Point		Total Concentration: Aerosol, Liquid, and Vapor	
	Maximum number of particles per m³			°C	°F	mg/m³	ppm/w/w
0	As Specified			As Specified		As Specified	
1	100	1	0	≤ -70	-94	≤ 0.01	≤ 0.008
2	100,000	1000	10	≤ -40	-40	≤ 0.1	≤ 0.08
3	—	10,000	500	≤ -20	-4	≤ 1	≤ 0.8
4	—	—	1000	≤ +3	38	≤ 5	≤ 4
5	—	—	20,000	≤ +7	45		
6				≤ +10	50		

How is Oil Injected Into the Compressed Air System?

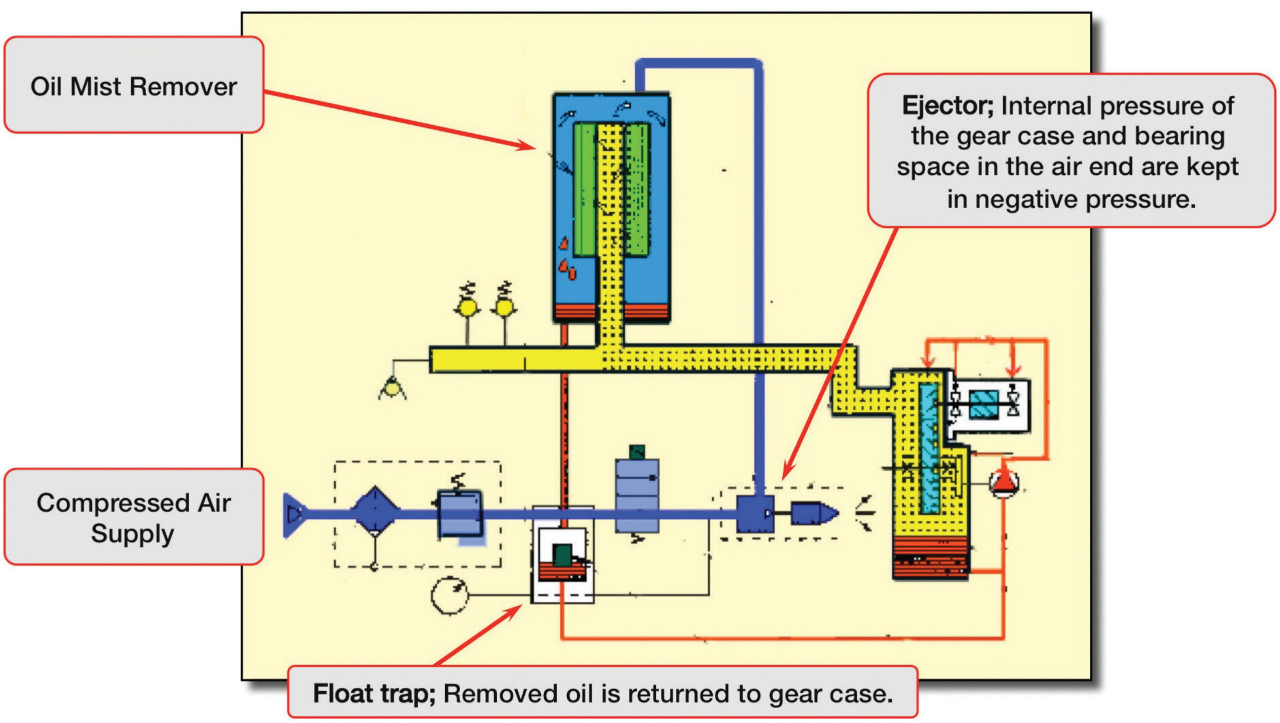
Who injected the oil into the compressed air? There are two sources; ambient hydrocarbons and the lubrication systems of oil-flooded air compressors.

Airborne hydrocarbon content of 6-10 ppm is normal even in a residential neighborhood. In a heavy industrial area with significant vehicle traffic, hydrocarbon content has been measured at 16-24 ppm. In many cases, 20-30 percent of these hydrocarbons may be condensable. One compressed air system found, in a pharmaceutical plant, prevailing winds back-drafting the air coolers while the parking lot emissions were adjacent to the compressor intakes – and the audit found substantial oil in the air system.

Another source of ambient hydrocarbons can come from lubricant sump demisters on machinery (including oil free air compressors) located in the factory. In an audit of a semiconductor facility, where the client had installed heat recovery on his air-cooled, non-lubricated rotary screw air compressors, the oil sump demister was discharging into the air. The return air duct on the heat recovery system was returning the sump blow-off back to the inlet of the compressor.

A patented process exists to eliminate the risk of air compressor sump oil mist being reintrained by the compressor intake. This patented process creates a closed-loop gear case oil mist removal system that recycles the oil to the gear case. One to three cfm of compressed air is regulated through a venturi. The venturi pulls a vacuum on the gearcase and pulls the oil mist into a coalescing filter. The oil is removed from the bottom of the housing, by a float trap, and returned to the gear case.

The Hitachi Patented Closed-Cycle Oil Mist Removal System



1. Oil mist from GC vent is removed almost completely (99.99%).
2. Removed oil is automatically returned to gear case. Reduces need for make up oil.
3. Gear case is kept in negative pressure to ensure zero oil migration through seal system.

Oil-flooded reciprocating and rotary screw air compressors are the primary "injectors" of oil into the compressed air stream. Oil is the required lubricant used in this technology to have a long-life and durable machine. Dependent on the age of the compressor and preventative maintenance programs performed, a lubricated rotary screw air compressor will introduced 2 to 10 ppm/w of oil into the air system. A well maintained 250 scfm lubricated air compressor, with a conservative 4 parts per million carry-over, will add up to 4.8 gallons (18.2 liters) of oil into the air system over an 8000 hour operation.

Applications requiring oil free compressed air must be aware of and manage both of these potential "injectors" of oil into the compressed air stream.

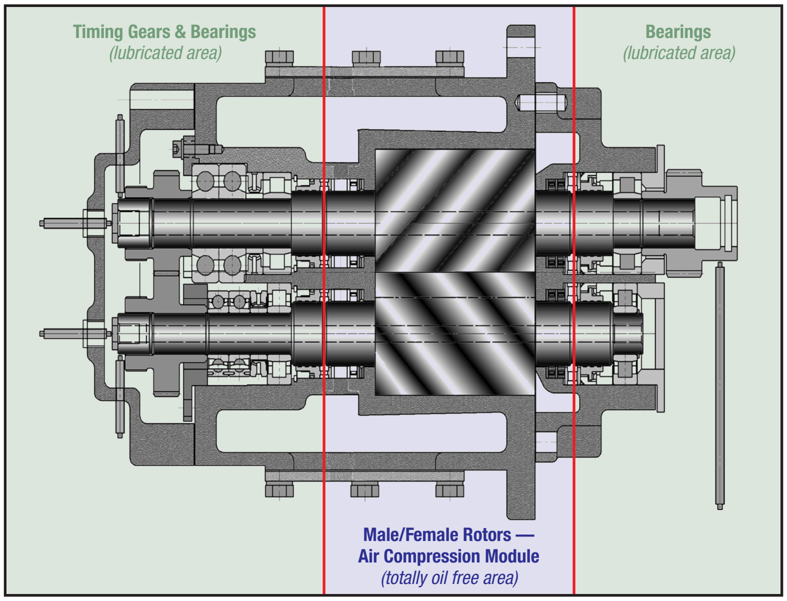
TABLE 2: GALLONS OF OIL ENTERING COMPRESSED AIR SYSTEM PER YEAR*[vi]

Concentration PPMw	Time (Hours)	25 HP (19kW) 100 scfm	50 HP (37kW) 250 scfm	100 HP (75kW) 500 scfm	200 HP (149kW) 1000 scfm
2	2000	0.2	0.5	1.2	2.4
	4000	0.5	1.0	2.4	4.8
	8000	1.0	1.9	4.8	9.6
4	2000	0.5	1.2	2.4	4.8
	4000	1.0	2.4	4.8	9.6
	8000	1.9	4.8	9.6	19.2
6	2000	0.7	1.8	3.6	7.2
	4000	1.4	3.6	7.2	14.4
	8000	2.9	7.2	14.4	28.8
8	2000	1.0	2.4	4.8	9.6
	4000	1.9	4.8	9.6	19.2
	8000	3.8	9.6	19.2	38.4

** With a well-maintained lubricated rotary screw air compressor.*

How is Oil Removed From the Compressed Air System?
The most common train of thought here is "don't put oil into the system in the first place." This is why oil free air compressors are the standard specification for the pharmaceutical and semiconductor industries. The popularity of oil free air compressors has grown significantly, over the past ten years, as other industries such as food, automotive, machining centers and glass autoclaves adopt oil free technology.

Oil free air compressors do not allow the lubricant to ever come into contact with the compressed air stream. Lubricant is only required for the bearings and timing gears, which is segregated from the compression chamber. This compressor technology presents no risk of lubricant migrating into the process air.



One myth in compressed air systems is that the use of an oil free air compressor frees the system of any compressed air treatment requirements. This is not the case. As mentioned earlier, the potential always exists that ambient air ingested by the air compressors (whether they are oil-flooded or oil free designs) will contain condensable hydrocarbons. These airborne hydrocarbons will condense into liquid downstream in the compressed air piping. Compressed air dryer and filter banks are therefore always required to ensure oil free compressed air.

Because compressed air may come in direct or indirect contact with products being manufactured, an elevated level of filtration is required. A high efficiency coalescing filter capable of removing solids and liquids is recommended. It should be capable of removing solid and liquid aerosols 0.01 micron and larger. The remaining oil content should be 0.007 ppm, or less. An activated carbon filter, installed in series, is also recommended downstream of the coalescing filter. The adsorption filter will remove trace odors and oil vapor to 0.003 parts per million by weight. This filter combination will ensure specified filtration levels achieve ISO 8573.1 Class 1 for oil and vapor removal.

Desiccant air dryer

Oil removal filter

Patented Closed-Loop Gear Case Oil-Mist Removal System

A patented process exists to eliminate the risk of air compressor sump oil mist being reintrained by the compressor intake. Hitachi oil free rotary screw air compressors do not vent oil mist to atmosphere. This patented process creates a closed-loop gear case oil mist removal system that recycles the oil to the gear case. One to three cfm of compressed air is regulated through a venturi. The venturi pulls a vacuum on the gearcase and pulls the oil mist into a coalescing filter. The oil is removed from the bottom of the housing, by a float trap, and returned to the gear case.

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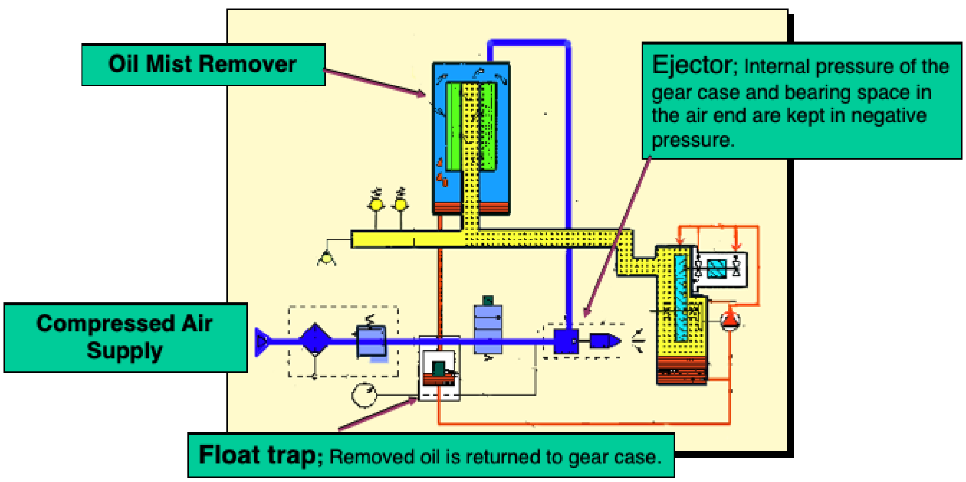

Conclusion

Most industrial processes have zero tolerance for the introduction of oil into the end product being manufactured. Any oil contamination can cause production shut-downs, product spoilage, and even FDA violations requiring plant shut-down. Industries requiring oil free compressed air include plastics, food, automotive painting, semiconductor, pharmaceutical, as well as many others. The International Standards Organization has issued the ISO 8573.1 Air Quality Classes, for compressed air, permitting engineers to place a clear specification on the air quality they require in their process.

There are two sources of oil being injected into the compressed air system. They are ambient hydrocarbons and the lubrication systems of oil-flooded air compressors. The prevailing trend today is to not introduce oil, in the first place, into the compressed air system. Oil free air compressors, with the appropriate air dryers, coalescing filters, and oil vapor removal filters, have become the preferred system solution to ensure ISO 8573.1 Quality Class Zero or One (oil concentration) reliable compressed air.

For more information, please contact

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i. *Kjell Lyngstad, Bosch Rexroth Pneumatics, "Milking the Benefits of Pneumatics", Compressed Air Best Practices Magazine, October 2006, page 28.*

ii. *Rod Smith, "Oil in the Sausage", Compressed Air Best Practices Magazine, August 2007, page 13.*

iii. *Jay Francis, "A Discussion on Air Quality Standards ISO 8573.1 and ISO 12500", Compressed Air Best Practices Magazine, August/September 2009, pgs 26-32*

iv. *Scot Foss, "Air Compressor Inlet Contaminants", Compressed Air Best Practices Magazine, August 2007, page 16.*

v. *Scot Foss, "Air Compressor Inlet Contaminants", Compressed Air Best Practices Magazine, August 2007, page 16.*

vi. *Jay Francis, "A Discussion on Air Quality Standards ISO 8573.1 and ISO 12500", Compressed Air Best Practices Magazine, August/September 2009, pgs 26-32*