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ABSTRACT: "The Anatomy of a Clean Room Dryer"

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How will a clean room dryer be different from a "normal" dryer? How "clean" is "clean"? Isn't Class 10,000 better than Class 1000? The term "Clean Room" can denote many different things to different manufacturers. This paper will discuss the reasons for and techniques used in the design and fabrication of a clean room dryers.

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INTRODUCTION

As the world of coatings, substrates, and applications become more specialized, converters are finding themselves searching out new market sectors and developing new products to fill needs that didn't exist as recently as five years ago. Equipment manufacturers are constantly being challenged to provide new and better equipment to meet the requirements of these new products, and the "Clean Room" seems to be on a lot of people's minds these days.

There are many applications that require clean room environments. Some of these would be optical films – consider window films, the screens on laptops, mobile phones, PDA's and other flat screen technologies. Other applications involve medical-related products, or others that may require FDA approvals.

The goal of this paper is to briefly discuss the aspect of a clean room dryer from the ground up, literally down to the nuts and bolts, and other design aspects that must be taken into consideration once it is determined that a dryer will be going into a clean room application.

DEFINITION

First of all, it is important to have an understanding of what is meant by "clean room"? Section 2.1.1 of ISO 14644–1 defines a clean room as "*a room in which the concentration of airborne particles is controlled, and which is constructed and used in a manner to minimize the introduction, generation and retention of particles inside the room, and in which other relevant parameters, for example, temperature, humidity, and pressure, are controlled as necessary".*

There are several classifications for Clean Rooms. For this paper, I will use US standard terminology: Class 100,000; Class 10,000; Class 1000; Class 100 and Class 10 and Class 1. In the terminology of Clean Rooms, the smaller the number, the more refined the process. These numbers refer to the allowable particulate matter, sized in microns, found in a specific volume of air. In English measurements, this would be one cubic foot of air; Metric uses cubic meters.

A micron is 1,000,000th of a meter, or 0.00003937". As a reference, human hair is typically between 30 and 200 microns. A Class 1000 designation allows for up to 1000 particles in one cubic foot of air that exceed the size of 0.5 microns and larger, or seven particles per cubic foot of a size of 5 microns and larger. Table 1, below, indicates the allowable contaminant levels at the different designations.

Federal Standard 209E Airborne Particulate Cleanliness Classes

Class	0.1 micron	0.2 micron	0.3 micron	0.5 micron	5 micron
10	350	75	30	10	-
100	-	750	300	100	-
1000	-	-	-	1000	7
10,000	-	-	-	10,000	70
100,000	-	-	-	100,000	700

Table 1

To put this into perspective, a conference room is likely to have between 500,000 – 1,000,000 particles of 0.5 micron or less in diameter

So, how does one begin to design a system that will keep such small particulate matter from contaminating their product? The answer lies in the use of a HEPA Filtration system.

FILTRATION SYSTEMS

The HEPA (High Efficiency Particulate Air) Filter is the most commonly used filtration system, and it filters particles as small as 0.3 microns with a <u>minimum</u> efficiency of 99.97%. Since the great majority of all clean room applications that our industry is involved with would be Class 1000 or higher, the HEPA filters are sufficient.

There is another filtration system that could be used for even more demanding applications - ULPA (Ultra Low Penetration Air) filters. This system filters particles as small as 0.12 microns with an astounding efficiency of 99.9995%! However, the need for such efficiency is very unlikely in most industrial applications.

When sizing a bank of HEPA filters, it is important that the velocity of the air at the face of the filter does not exceed 500 fpm. The rule of thumb is to have one square foot of HEPA filter for every 500 cfm of supply air. Since a common size for the filters is 24" x 24" you will need one HEPA filter for every 2000 cfm of supply air.

MATERIALS OF CONSTRUCTION

Obviously, the materials of construction are extremely important when building a clean room dryer. Stainless steel is the preferred choice for both the dryer's interior and exterior, due to the corrosive nature of the solvents often used in cleaning of these dryers. While there are several choices of stainless steel, 304 and 316 are the most common. The decision between these two metals is dependant upon the solvents that will be used in wash down. Typically, 316 would be recommended when more caustic solvents will be used.

Another consideration will be the finish of the stainless steel. In most applications, a "2B" finish will be acceptable. It is readily cleanable, but markings from the manufacturer are visible. The next step up would be "4". This provides a cleaner look, as all of these markings have been removed. Another grade, "8", provides a mirror finish, and would only be used in special applications, which, more than likely would be process-related.

Once the grade of stainless steel has been determined, there are other materials that need to be considered:

- Gasket Material – Fiberglass needs to be avoided, as the fibers could enter the air stream, as the dryer will be run at a negative pressure. Non-fibrous gasket material is essential.
- Silicone – What will the temperature be? Will this be able to withstand the heat? Will it be able to handle any cleaning solvents that may be used?
- Fan Wheels – Need to be either stainless steel or have a coating, (such as Heresite).
- Motors in the clean room **cannot** be belt-driven, as the belt will become a source of contamination. It is preferable to have this remotely located.

DRYER STYLE

Since there are no moving parts on the interior of a flotation dryer, it is an obvious choice for a clean room dryer. Extra care must be taken with the rolls and bearings when considering a roll-support dryer.

Rolls are typically made of either stainless steel, nickel-plated or, a hard coated aluminum. It remains critical that no surface wear occurs. Bearings will be sealed or shielded.

HEAT SOURCE

Clean room dryers can have the same heat sources as other converting dryers. There are pros and cons for all of them, and your best alternative comes down to what sources are readily available, projected operating (production) time, size of dryer, etc.

For example, in the case of a lab or pilot line, an electric heat source may be a good alternative to consider. These are typically narrow-web applications that will not be operating in a continuous (24/7) environment. Depending on the size of the heating element, the initial capital outlay will not be as high. However, once the production demand increases, typically, the operational costs are make this alternative unreasonable.

Natural gas, the most common heat source in converting applications, can be used if placed in conjunction with an air-to-air heat exchanger. By segregating the gas flame, the products of combustion never enter into the airstream. This potential contamination source is avoided. While the cost of the heat exchanger increases the capital outlay over a standard gas-fired burner system, operational efficiencies outweigh these initial costs.

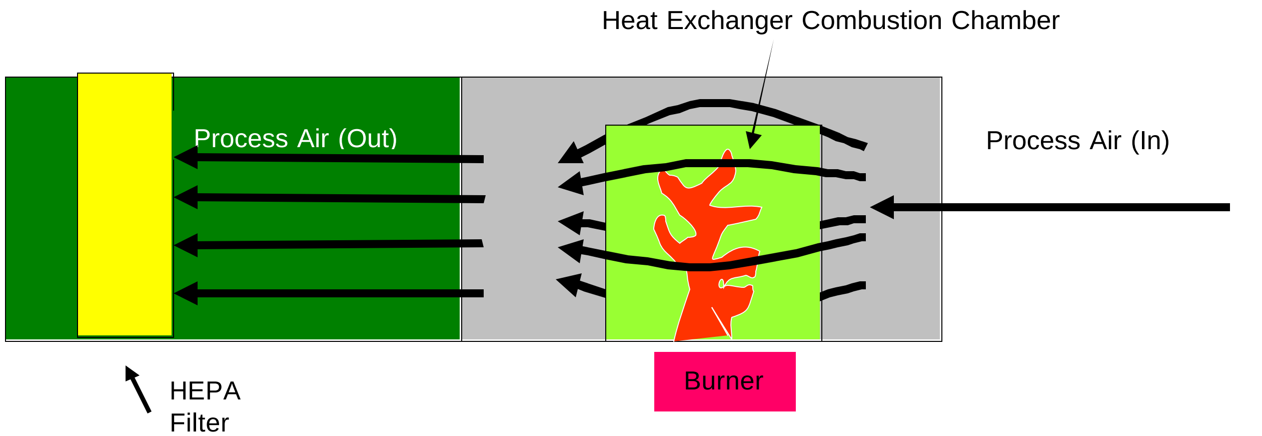

Figure - 1

Two alternatives to natural gas heat exchangers would be steam and hot oil. Each operates under the same principle of having air blow over a heated coil. These coils must be either made of stainless steel or coated with something like Heresite. Because the heat conductivity of stainless steel is not as high as many alternative metals, the size of stainless steel coils will need to be relatively larger than standard heat exchanger coils.

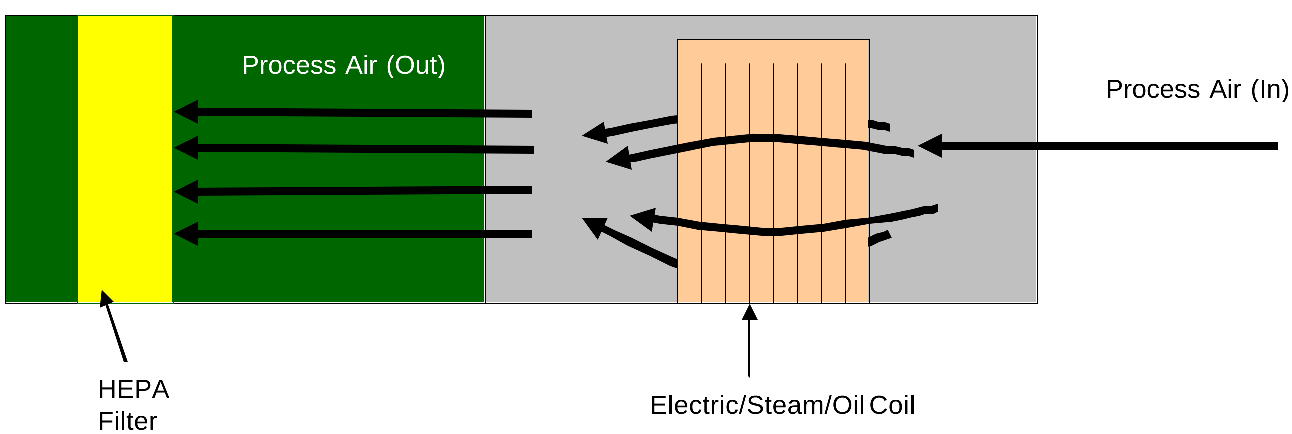

Figure - 2

There are, however, temperature limitations with steam. The Law of Diminishing Returns really comes into play when it comes to increasing pressure and the incremental gain of operating temperatures. For example, a steam source with 120 psi will provide 350°F, while you will need to go to 235 psi to get to 400°F. That translates to a substantial increase in steam pressure for a minimal temperature rise.

While an oil system enables the dryer to attain higher temperatures at lower pressure than a steam system, there will still be quite a bit of maintenance involved with the piping and valves associated with the oil system. Also, should there be a leak in the steam coil, the air stream will be contaminated. Typically, this system would only be used if excess capacity were available, and for economic reasons it would be a good choice.

No matter which heat source is going to be used, one way to reduce the total amount (and cost) of the stainless steel components is to have the plenums located in a "remote" location. i.e. either above the dryer or in an adjacent room. By placing such components in a segregated work area, the assemblies do not have to conform to the same clean room standards. The external components such as fan skids, plenums, filter boxes, and ductwork can then be made of a less expensive material, such as aluminized steel.

MANUFACTURING TECHNIQUES

Once the dryer design has been finalized, there are procedures that should be observed in order to maintain a certain level of cleanliness as the dryer is being constructed. All welds, metal edges and metal surfaces are to free of dust, fillings, oxides of metals and any other foreign contaminants.

When the shop personnel are assigned to the build a specific clean room dryer, all of their hand tools, grinders, polishers, welders, etc., are reserved for exclusive use on that dryer. Grinding wheels, brushes and abrasives will all be used only with stainless steel, avoiding any possibility of cross contamination with a mild steel or aluminized steel dryer.

In some instances it may be necessary to create a segregated area in the manufacturing facility will be made to reduce air borne dust or filings from adjoining fabrication areas.

The manufacturing process for a clean room dryer is also different from a dryer used for a conventional coating line using a water-based coating.

- Fully Welded Dryer: In many instances, a dryer can be spot-welded and any gaps are filled with silicone. However, since dryers should be under a slightly negative pressure, full welding eliminates the possibility of fiberglass contamination from the insulation.

This is also important when using solvents in the coating. If the weld is not complete, it's possible for a small hole to develop, allowing some external air to enter the dryer. When this cooler air comes into contact with the solvent-laden hot air, condensation will take place. In order to assure that this does not occur, we take the extra step of dye checking all of the welds, see Figure – 4, below.

Dye Checking Welds

Figure – 3

- Weld Quality: Since clean up plays an important role in the design and end use of a dryer, the quality of the welds is critical to the process.

Welding Quality Classifications

Class I	Class II	Class III	Class IV
Sharp Edges	No Sharp Edges	No Sharp Edges	No Sharp Edges
Some Spatter	No Spatter	No Spatter	No Spatter
	60 Grit Finish	100 Grit Finish	100 Grit Finish
	Weld Discoloration Present	Weld Discoloration Acceptable	No Weld Discoloration
		Easily Cleaned	Polished with Abrasive Wheel
		Snag Free with Cotton Cloth	Snag Free with Cotton Cloth

Table - 2

Welding Quality Examples

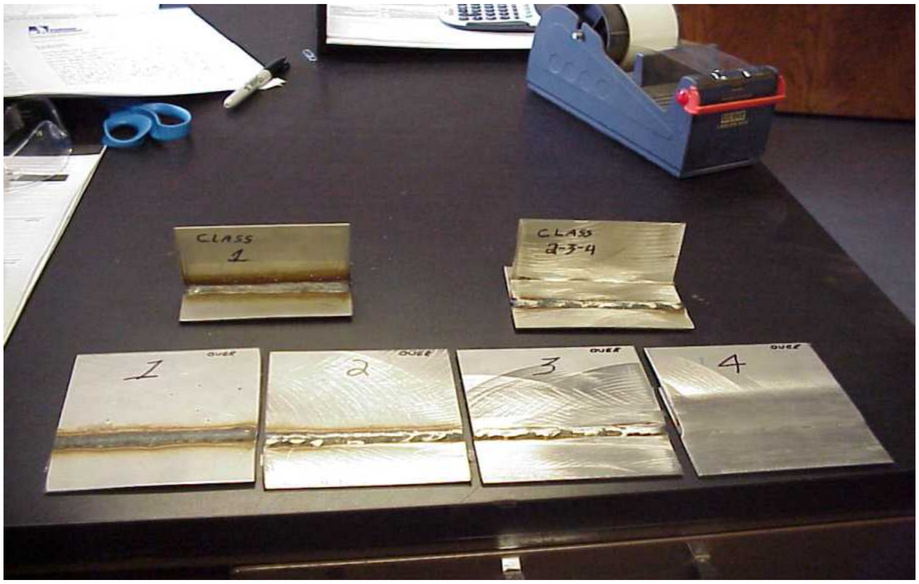

Figure - 4

Another aspect that involves the process of easily cleaning a dryer is to avoid horizontal cross members when possible. Dryers are typically made with tubular steel cross supports and structures. A simple design feature is to rotate these supports 45°. This eliminates a flat spot for dust, dirt or other debris to accumulate.

Cross-Member Illustration

Figure - 5

Figure - 6

In locations where these flat surfaces are unavoidable, such as header connections, extra care will be taken to seal any openings with silicone. Filling in these spots eliminates another possibility for the accumulation of any contaminants.

Silicone Filling

Figure - 7

The use of tubular steel to support the air bars instead of a C-Channel eliminates another spot where contaminates may collect. There are no nooks and crannies for any debris accumulation, and it provides an easily cleaned surface.

Tubular Steel Construction

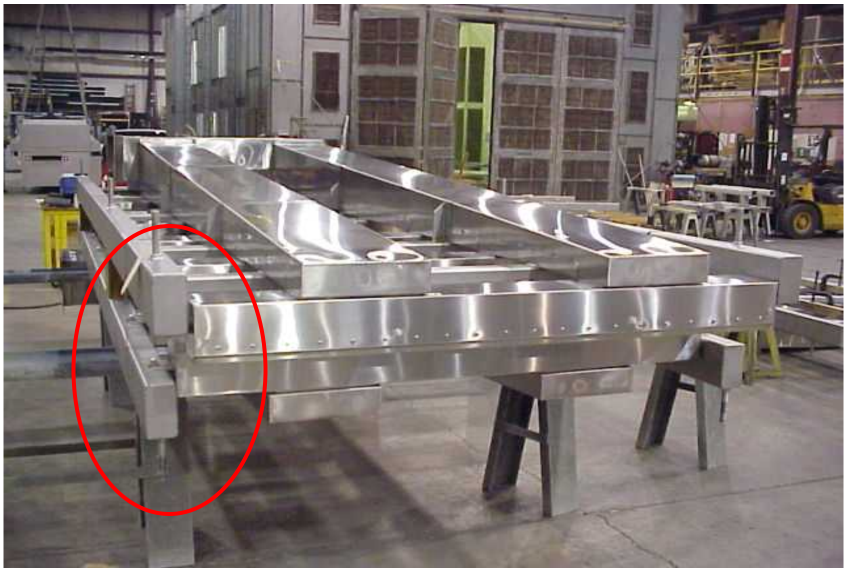

Figure - 8

In locations where mounting brackets are used, specially designed covers are implemented.

Figure – 9

Even the nuts and bolts are important when building a clean room dryer. “Acorn nuts” are used to avoid any exposed threads, and to allow for ease of wipe down.

Acorn Nut

Figure - 10

Like snowballs, all of these “little things”, if done correctly greatly facilitate the cleaning of a dryer once it has been installed and working in a production environment. In some instances, drain plugs have been installed if the customer wanted to use a hose to spray down the inside of the dryer, or access doors have been installed to allow for additional cleaning and maintenance.

As the components are being completed, extra care must also be taken in storage and cleaning. Work in process parts and subassemblies (air bars, headers, and enclosures) are thoroughly cleaned by hand or, in some instances, by pressure steam cleaning using an appropriate commercial detergent or acid cleaning solution.

All surfaces, inside and out, will be free of dust, filings, oils and construction marks or notes that may have been written on any metal surface. Once cleaned, these subassemblies will be covered in plastic until required for final assembly.

When the assembly has been completed, the entire module will be inspected for cleanliness, surface finish and general appearance. A final cleaning will take place on all exterior and accessible interior surfaces with the appropriate cleaning solution. Once the final inspection has taken place the module will be shrink wrapped and covered, in preparation for shipment. This will eliminate any dust contamination that may take place during shipping.

Once these factors have been taken into consideration, the end result can look like this…

Figure - 11

…or this

Figure - 12

Conclusion

The cost associated with clean room dryers is substantially higher than a typical converting oven. While it should be clear that the material cost would be substantially higher, the labor factor should not be overlooked. If we consider a standard converting dryer, two zones, each twenty feet in length a ballpark estimate for labor would be approximately 2200 man-hours. If one looks at an identically sized dryer with a clean room design, this labor now leaps to about 3300 hours!

There are many aspects that need to be conveyed to the equipment manufacturer in order to have the dryer meet the product specifications for cleanliness of the airstream, the frequency of cleaning, as well as the solvents being used. This will all have an impact on the materials being used, as well as the amount of labor that will be used in the manufacturing process - welding, grinding and polishing of these welds.

Just as there are many applications for clean room dryers, there are different ways to approach the design, fabrication and installation of these dryers. It is critical that both the supplier and customer have a very good handle on the process, procedures and expectations. It is significantly easier to make changes on paper than to make corrections on the manufacturing floor. While it is always essential to have good communication after the sale has taken place, it becomes even more critical with a clean room dryer, where materials, engineering and manpower all have to go to a much higher level of quality.