GORE® Filtration Products

White Paper

IMPROVING AN EAF AIR POLLUTION CONTROL SYSTEM USING NEW FILTER TECHNOLOGIES

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INTRODUCTION

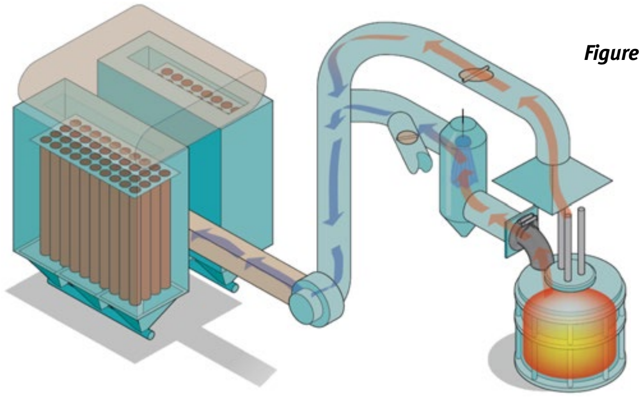
As steel producers explore innovative technologies to improve the capacity and efficiency of their meltshops, they frequently bump up against the limitations of their Air Pollution Control Systems. Rather than take the expensive approach of making those systems larger, some producers are focusing on improving the capacity and performance of their existing APC systems. This paper explores how several producers' use of new efficient, low-resistance filter media has increased the capacity of their systems 20% and more, improving their meltshop environmental quality. Economic and technical considerations are explored, together with impacts and considerations on a plant's environmental permitting.

DISCUSSION

Air Pollution Control (APC) Systems In EAF Steel Plants

The primary form of pollution control for Electric Arc Furnace (EAF) meltshops in most of the world is a fabric filter, also known as a baghouse, filtering the gases drawn directly from the shell of the EAF through a Direct Evacuation System (DES). These gases are frequently combined with the secondary fugitive fume control gases drawn from the meltshop roof or overhead canopies, as conceptually shown in Figure 1. Such systems may employ gas cooling technologies for the DES gases, and frequently require multiple fans to achieve the desired total gas volumes necessary[1].

Figure 1



Over the years technology, engineering, and operational advances have been focused on the EAF, improving its efficiency, productivity, and production rate[2]. Faster tap-to-tap times, increased chemical energy input, reductions in scrap quality, oxygen lancing and foaming slag practices all contribute to more loads placed on the APC system. As a result, the APC system, which may have been adequate when it was first installed, becomes undersized, or can develop operating problems from being over-stressed. At the baghouse, these problems can take the form of short filter life, excess emissions, and high pressure drops. This last problem – high dPs – can result in either a higher energy bill at the fan motors to overcome the resistance, or a reduction in the total amount of gas flow coming from the meltshop. Even in baghouses that are conservatively sized and operated well, the overall resistance of the existing system may not allow for EAF operating advances being contemplated by the steel plant. In such cases, the result is a "dirty" meltshop, where excess fumes escaping from the furnace shell, and/or fugitive fumes that are not adequately captured by the overhead canopy, are not evacuated from the meltshop by the APC system. When this happens, the shop is left with the options to keep the fume within the building, causing production slow-downs and worker health issues, or allow it to escape the shop, where it becomes an environmental problem.

When addressing this problem, Fereday et. al.[3] showed that an economical first approach is to address the direct draft on the furnace itself. It is much more effective and economical to control the fugitive emissions at the source rather than trying to capture them dispersed in the meltshop air. This method requires reliable furnace pressure measurement and control, with the aim to run the actual furnace pressure as close to neutral (zero) to slightly negative (-1 mm) as possible. While the fluctuating nature of the EAF makes perfect furnace pressure control difficult or impossible, as an operating strategy it affords the steel plant with the best combination of fume control without causing electrode penciling or furnace heat loss (from pulling too much air). Such a "high temperature approach" requires analysis of the water cooled duct and other cooling technology capacities, the capabilities of the fans to move the required amount of air at higher temperatures, and frequently filter bags that are capable of handling the hotter gases. This strategy has been successfully employed at a large number of hot, fast furnace mills around North America, with the use of ePTFE membrane/fiberglass laminate technology used in the baghouse.

However, this approach does not directly address the meltshop conditions that prevail during charging and tapping operations, nor does it address those situations where additional draft from the DES is neither feasible nor practical. It also does not address the need for improved fugitive emission control after the "high temperature approach" has already been employed. In these cases, draft capacity increases are frequently needed to allow for better capture at the canopies, and for additional hoods and capture of ancillary processes that add to the overall meltshop load (Ladle Metallurgy Furnaces, for example).

The typical approach to increasing the overall gas flow from a meltshop is to go bigger – bigger fans, bigger motors, bigger (or more) ductwork, bigger cooling systems, bigger (or more) baghouse(s). There is of course a daunting capital cost to these approaches, so that such projects require a pressing or dramatic environmental problem, or an equally compelling production improvement payback. What is not as often considered is that “bigger” costs more to operate, frequently resulting in a higher cost per ton of steel produced. Increased costs include things like additional mechanicals to maintain (dampers, rotary air locks, door seals, plugged hoppers), higher energy costs, and more manpower to inspect and change filters.

In the past two decades, the use of ePTFE membrane filter media has been used to reduce the overall pressure drop, and hence filter drag, in problem baghouse systems where the installation costs and/or the operating costs of a system expansion were considered too high[4]. This media consists of an efficient membrane of expanded PolyTetraFluoroEthylene laminated to an appropriate substrate to improve the filtered particulate release properties of that filter medium. This membrane was most normally applied to a fiberglass medium in typical Reverse Air baghouse applications, to also take advantage of the “High Temperature Approach”, but it has also been used with polyester, aramid, and acrylic backers. This laminate lowers resistance by keeping the dust cake closer to the filter surface, where it can be more easily removed during the cleaning cycle. However, even with this highly efficient, durable filter surface, some fine fume would still stay on and in the surface of that membrane, and would continue to accumulate over time (years, but still an accumulation). Meanwhile EAF technology and operating practices have advanced to the point of needing another step change in this type of filter performance to continue to consider this type of technology as an cost-effective alternative to a bigger APC system.

GORE® LOW DRAG™ ePTFE Membrane Filtration Media

As has been presented in previous AIST publications, a new form of this ePTFE membrane technology has been introduced to the EAF market[5]. This media has proven to be effective in lowering the resistance to flow (Filter Drag) even in “happy baghouses” – those that, based on historical operating history and industry norms, would be considered to be operating well. The key difference in this filter medium compared to previous ePTFE membrane media is its much higher surface efficiency, even against sub-micron particulate matter. This allows for an enhanced dust cake release better than standard membranes, and much better than non-membrane (conventional) filter materials. It has proven to be equally robust and durable in use, making it worthy of evaluation for a plant needing additional gas flow through their APC system.

Much has been written on the subject of Filter Drag in industrial filtration applications, and the reader is kindly directed to any of those publications for education or review[5,6]. As a simple reminder, the definition of Filter Drag is presented in figure 2.

$$\textbf{Filter Drag} = \frac{\text{Differential Pressure}}{\text{Air to Cloth Ratio}} = \frac{dP}{A/C} = \frac{\text{"wg}}{\text{cfm}/\text{ft}^2}$$

Figure 2

These units are typical in the US market; elsewhere, typical units might be kPa/m^3/m^2-min, or mmH$_2$O/m^3/m^2-hr. Lower is better, as long as you are not sacrificing collection efficiency or filter durability.

Filter Drag and APC System Airflow

APC systems can be quite complex and complicated – various dampers, ductwork configurations, fan arrangements, cooling systems, and different styles of baghouses all contribute to a large variety of situations. There is a resistance to flow through all of these systems that must be overcome by the APC system fan(s) in order to move air and gases from the EAF and meltshop, through the filter and out to the atmosphere. All of these individual restrictions can be reduced in concept to two primary considerations: mechanical restrictions (those from the dampers, systems and ductwork), and the filter restrictions (flow through the filter media). When combined into an overall system resistance equation, the graph of this resistance verses flow rate through the system takes on a parabolic shape as presented in Figure 3.

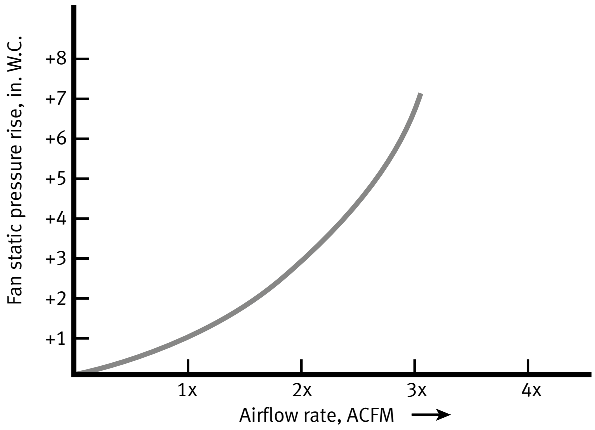


Figure 3

When the flow through the system is zero, there is no pressure drop. As the flow rate increases, the pressure drop of the system goes up by some parabolic function. How “steep” the curve is depends on the restrictions in the system – if there are many, or if they are severe, the curve will be very steep. If the restrictions are few, or if those restrictions still allow for the easy passage of gas flow, then the curve will be more shallow.

The mechanical pressure losses of a given system design can be easily predicted in advance of a system being built, and/or measured once the system is in place. It is also well understood how mechanical losses vary as the flow of gases through the system change – there are many good resources on this subject available to the competent industrial ventilation engineer[7]. Flow through the baghouse can be a bit more problematic in that the resistance in that filter changes with time – dust characteristics, load, cleaning frequency, and filter permeability. However, baghouse OEMs, filter suppliers, and industry consultants can use the concept of a generalized Filter Drag to predict typical resistance performance for a given filter, at a given Air-to-Cloth Ratio (ACR), in a typical application (Steel EAF combined DES and Canopy, for example). When these resistance factors are combined, a system resistance curve (as illustrated in Figure 3.) can be determined.

The device(s) that actually moves the gases through that system is the fan. In almost all Steel EAF applications, that fan is a centrifugal type. Such fans are capable of moving large quantities of air while at the same time generating enough pressure to overcome the restrictions of the APC system. Centrifugal fans are described by their own characteristic curve, their so called "Fan Curve", as presented in Figure 4.

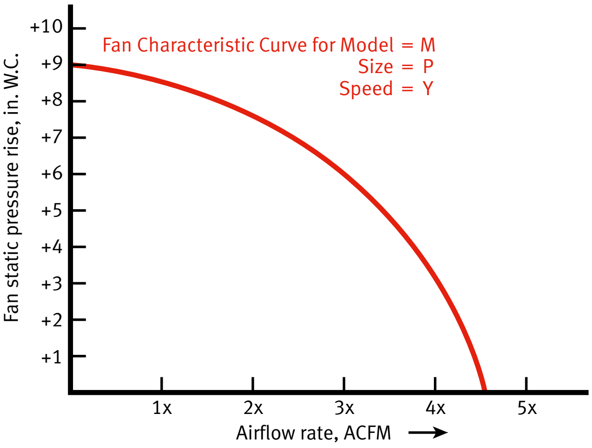


Figure 4

The Design Operating Point is then the intersection of the Fan Curve, and the System Curve, there the flow and pressure performance of the fan match the system resistance at that flow rate, as shown in Figure 5.

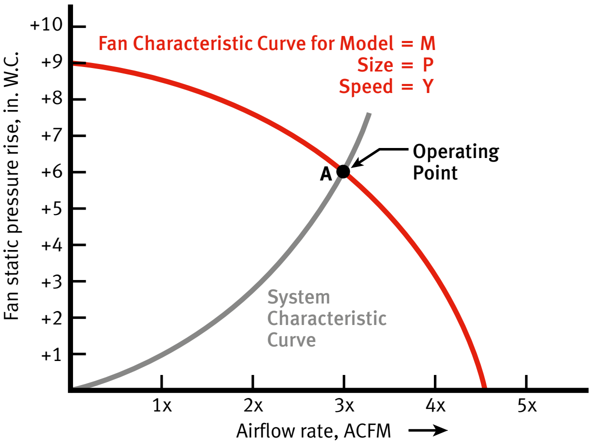


Figure 5

Fan Performance Curves are usually presented along with the fan power requirement curve, and sometimes with a fan efficiency curve. An example of a horsepower curve might look something like Figure 6.

The power requirement would be determined by the intersection of a vertical line drawn through the operating point (designating the system flow rate) and the power curve.

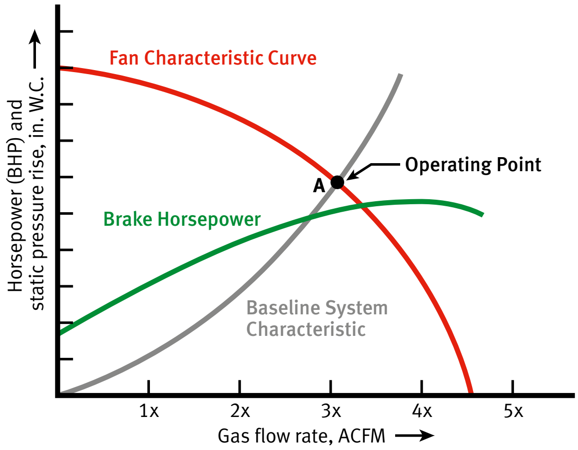


Figure 6

All of these fan performance curves are drawn under standardized test conditions, and therefore must be adjusted for temperature, ambient pressure, fan speed and the like. These corrections are relatively straight forward and supported in various literature and reference materials[8].

Once the actual Baseline System Curve, and the actual Fan Characteristic Curve(s) are determined, it is now possible to make predictions on flow, power, and pressure changes in the system. If one assumes that there are no changes in the ventilation system mechanicals, then as filter bags plug up with dust, or fail to release all of the particulate upon a cleaning cycle, then the pressure drop, and the resistance to flow, of the baghouse goes up. This makes the system curve steeper, as can be seen in the Increased Resistance Curve in Figure 7:

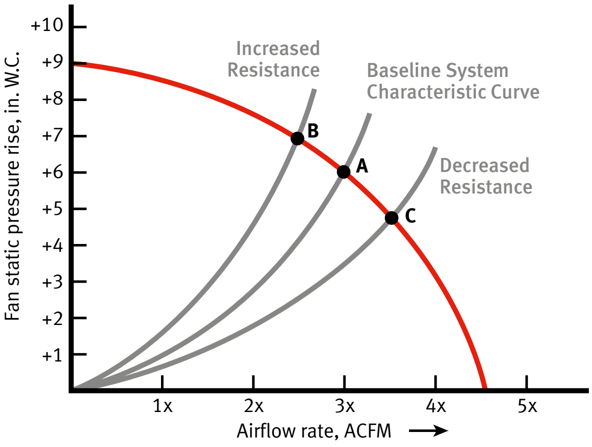


Figure 7

In the case of a desired airflow increase, one can see that one must reduce the resistance in the system curve (make it shallower), and find the new system curve/fan curve intersection point, as illustrated in Figure 7. The new intersection point (Point C) represents the new operating point, and shows the potential flow rate increase for such a drop in system resistance.

It is clear that changing the filter medium in the baghouse is not the only way to reduce system resistance. It should be obvious that when looking for an efficient way to increase furnace draft and meltshop evacuation, care must be taken to ensure that the ductwork remains clear and clean, that all dampers are functioning and are completely open when they should be, and that all unnecessary restrictions are removed or modified. For example, cooling systems and/or cyclones that may no longer be necessary with the use of efficient, high temperature-capable membrane filter media can be by-passed or removed.

Limitations and Considerations

Moving a mass of air from one place to another takes energy, and moving more of it takes more energy. Remembering the fan curve from Figure 6, decreasing the operating point and moving the operating point down and to the right also means an increased requirement for fan power. At a simple, high level, with everything else the same this means more amps to the fan motor. If a system was already operating at full-load amperage, there may not be enough extra power in the existing motor to get the job done. However, there is another consideration, and that is the fan efficiency. The fan efficiency describes the ability of a particular fan wheel to convert mechanical power (that to spin the wheel) to air movement. Frequently the fan efficiency is also plotted on the fan curve, and it may look something like Figure 8:

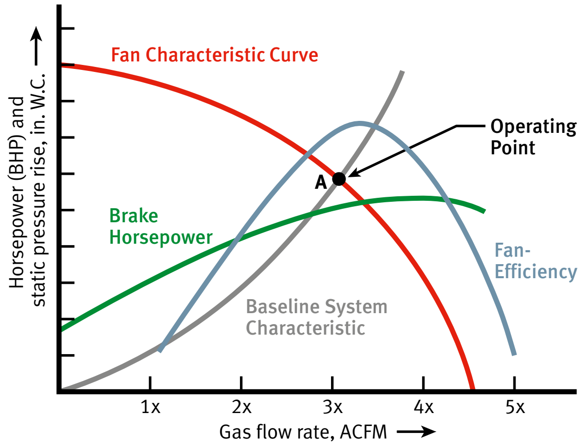


Figure 8

If moving the Operating Point to the right (reducing system resistance) means that the fan moves into a higher efficiency operation, there may be less of a power penalty to pay at the fan motor, and increases in gas flow may be achievable with a minor change in overall amperage. If, however, moving the Operating Point results in a lower fan efficiency, the airflow increase may not be possible even with "room" with the fan motor amps.

Within limits, fan wheels can be re-designed to operate at high efficiencies corresponding to the new low resistance operating point. In some cases, this can allow for an airflow increase even where the motor is limited – in other cases, this can reduce the total amount of power used by the fan motor to achieve the increased airflow.

Aside from the fans and fan motors, one must also know the overall baghouse capabilities when contemplating a system flow rate increase. Invariably, increases in system airflow are meant to capture more fume and particulate. This means that the overall dust load to the baghouse will increase as well as the gas flows. Reviews of the dust removal and storage systems must be conducted to be certain that the hoppers will not fill up. The additional dust load may also necessitate a faster cleaning cycle – can that system handle that change? The velocities of the gases entering the baghouse must remain below good engineering values to prevent sand-blasting and abrasion of the filters.

In all cases, a careful but straight forward engineering study of the existing APC system, including the baghouse and the fans, is necessary to confirm whether the use of the new GORE LOW DRAG Filter Bags, and/or other resistance reducing technologies, will result in the desired operating performance.

Lastly, but just as important, is a review of the plant's environmental operating permits. Depending on how those permits were written, increasing plant airflows may cause a permit problem, where the increased airflow increases the plant's "potential to emit". While an increase in meltshop draft may actually be a positive for the environment and compliance, a review and change to the operating permits may still be required, and such reviews are not cheap. The good news – the new GORE LOW DRAG Filter Bags have a much higher collection efficiency than standard ePTFE membrane laminates, and initial field emissions measurements have shown a significant reduction in overall baghouse emissions, so the ability to show a net zero change, or even an improvement, in overall plant emissions makes those discussions with regulatory authorities easier.

Field Experience

After a trial of this new low resistance filter medium confirmed its cleanability and performance, a US-based steel plant installed their full reverse air baghouse with GORE LOW DRAG Filter Bags, replacing a standard ePTFE membrane/fiberglass fabric filter. They operate a system with six fans. It was their intention to obtain a 20% increase in overall system flow rate through a combination of a lower baghouse resistance and the efficient use of all of their fans.

Typical total system flow rates with standard ePTFE membrane bags were between 900,000 – 915,000 scfm, with corresponding baghouse pressure drops of 7 to 8 inches w.g. After installation of GORE LOW DRAG Filter Bags, and with all six fans in operation, the plant was able to obtain flow rates of 1,050,000 to 1,150,000 scfm. At this new flow rate, the average pressure drops across the baghouse are 4½ to 5½ inches w.g. Not long after the total airflow tests, one of the fans showed unacceptable vibrations and had to be shut down. It was observed that with a five fan operation, the plant was still able to maintain their original flow rates (915 kscfm), even though the fans were now operating at a slightly lower fan efficiency.

The plan moving forward is to repair the sixth fan to allow for the flow increase, and then look at fan wheel modifications to improve fan efficiencies at the new stable operating points, thus reducing energy costs at the new flow rates. After six months of operation, GORE LOW DRAG Filter Bags were still performing at the same filter drags, with no degradation in pressure drop or emissions performance.

It should be noted that this particular plant had envisioned wanting airflow increases as part of their overall plant operating plan, and had written them into their environmental permits. They have a good relationship with their local regulators, such that there have been no compliance problems with this change in plant operations.

CONCLUSION

As steel plants continue to innovate and develop ways to make steel faster and more efficiently, their air pollution control systems must also be upgraded with cost effective, innovative new strategies, engineering, and filter products. Just as these plants are making more steel, and better steel, with the same furnace(s), so too must they expect more gas flow, and better performance, from those APC systems. A new ePTFE membrane filter technology – GORE LOW DRAG Filter Bags – offers the opportunity to do just that, but such a change in filter performance must be done in conjunction with a thorough review of the capabilities of the other system components, such as fan and fan motor capabilities. Lowering the resistance of the APC system has many economic benefits, and also provides an economical opportunity to improve the compliance performance of the entire meltshop evacuation system, without making major changes to that system. Although significant system, equipment, and regulatory considerations must be addressed, the lower capital costs of such an approach, taken together with the opportunity for operating cost benefits, make this effort well worthwhile, and such results have already been realized by the steel industry.

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