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TECHNICAL BULLETIN

The Engineering Challenges of Combining Multi-Venue Kitchen Ventilation Systems into a Centralized Exhaust Fan

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Background:

A growing trend in the Food Service and Restaurant Industry is the development of dense food halls, ghost kitchens, and similar high-density multi-venue operations. These establishments offer guests a wide variety of food options and flavors from different food vendors in a single convenient location.

Unfortunately, these venues often face restrictive structural and architectural requirements, leading to a substantial engineering challenge for the HVAC and Kitchen Ventilation system. Due to limited roof or exhaust grease duct space some design teams may elect to combine multiple kitchen venues into a central exhaust duct, fan, or pollution control system.

This bulletin will explore the engineering risks and downfalls of designing multi-venue systems with a centralized exhaust and fan, as well as suggest engineering best practices to lead to high quality, energy efficient, and sustainable operations.

The Ideal Multi-Venue Kitchen System:

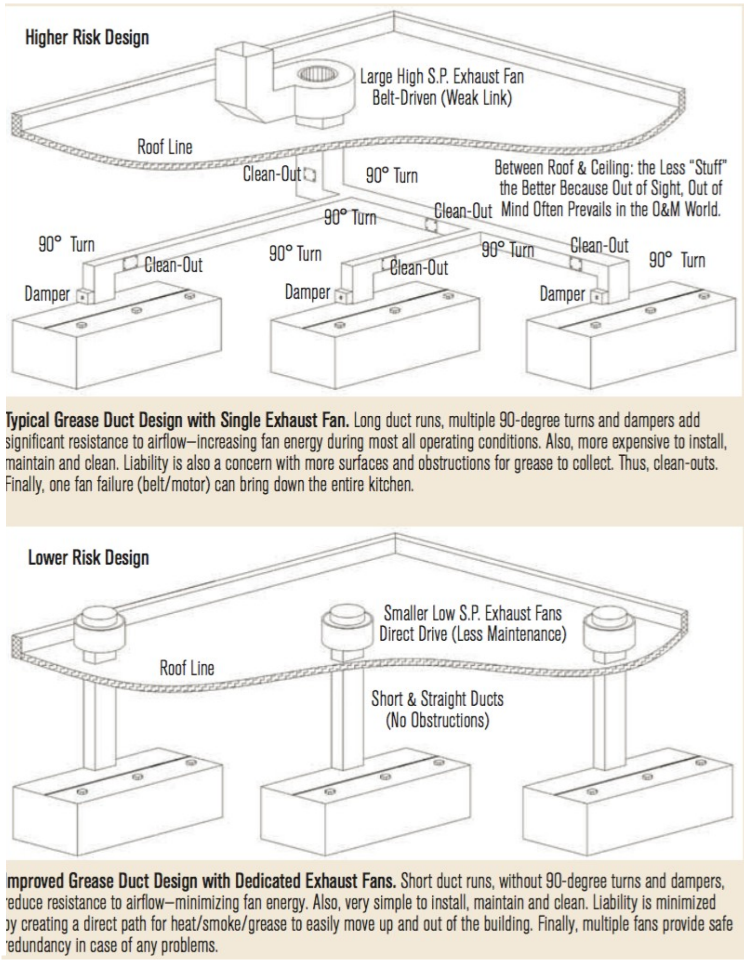
In an ideal setting, the most efficient multi-venue kitchen ventilation operation is one that allows for:

Individual system operation- meaning that individual venues can run their hoods and make up air independent of other venues.

Independent exhaust duct runs- By avoiding the combination of exhaust duct runs, the individual venues are isolated from one another from a fire protection and risk element.

A requirement of NFPA 96, any hoods sharing common ductwork "shall be considered a single hazard area requiring simultaneous automatic fire protection in all hoods" (Section 10.3, 2017 Edition). As such, all fire systems must activate should any one system face a fire or malfunction, leading to costly downtime and substantial damage and inspection costs. As an example, a relatively simple ten venue fire system discharge will result in multiple days of downtime and a complete shutdown of the entire building operation while each individual fire system is recharged, reset, all food is thrown out, and all cooking equipment cleaned and cooking oils changed.

Individual exhaust fans for each hood- When each hood is covered by its own exhaust fan, the building ventilation system is designed with maximum sustainability in mind. The costs for individual fans are substantially lower when simple upblast style UL-762 fans are utilized, which often operate with fractional horsepower single phase EC motors, reducing electrical installation and operational costs. More importantly, these commodity type fans are readily available, replacement parts are in stock throughout the country, and service technicians can easily carry components to rooftops and install them in a matter of hours.



Typical Grease Duct Design with Single Exhaust Fan. Long duct runs, multiple 90-degree turns and dampers add significant resistance to airflow–increasing fan energy during most all operating conditions. Also, more expensive to install, maintain and clean. Liability is also a concern with more surfaces and obstructions for grease to collect. Thus, clean-outs. Finally, one fan failure (belt/motor) can bring down the entire kitchen.

Improved Grease Duct Design with Dedicated Exhaust Fans. Short duct runs, without 90-degree turns and dampers, reduce resistance to airflow–minimizing fan energy. Also, very simple to install, maintain and clean. Liability is minimized by creating a direct path for heat/smoke/grease to easily move up and out of the building. Finally, multiple fans provide safe redundancy in case of any problems.

Figure 1 Comparison of Ideal vs Combined Duct Systems[1]

Contrast this with a large centralized exhaust blower, which often operate with large specialty motors that weigh hundreds of pounds, offer no redundancy in case of failure, have substantial shipping costs in the event of a failure, require specialized craning equipment to move replacement blowers or motors into position, and may not be retrofit friendly at the end of their service life.

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What if there isn't room for the ideal arrangement?

It is understood that in many buildings structural and physical limitations will ultimately prevent the use of an individual exhaust fan and exhaust grease duct run on each venue within a multi-venue operation. Like all engineering challenges, compromise is required to meet operational needs without sacrificing quality and life safety.

Electronically Controlled Grease Dampers? Not a Valid Solution to the Problem

Some manufacturers have attempted to resolve the challenge of running individual grease ducts through the inclusion of what are often referred to as Automated Exhaust Balancing Dampers (ABD), or Modulating Grease Dampers.

Figure 2 Example of Automated Exhaust Damper

On the surface, ABD appear to be a valid solution to the operational problem of wanting individual hood control with a centralized exhaust duct system. The reality however is quite different.

ABD systems employ electromechanically controlled dampers in the grease laden exhaust duct system. Exhaust static pressure measurement devices are employed within the grease laden exhaust as inputs so that the grease dampers may have a reference signal for modulation.

Intuitively, any component within the grease laden exhaust air is subject to substantial abuse in the form of hardened grease deposits, aggressive hood/duct cleaning and chemicals, or in extreme cases, fire. It is not uncommon for such systems to have clogged pressure sample ports, binding or failure of damper mechanisms from grease disposition, and leaking of grease into the roof structure via damper shafts at the point of penetration through the exhaust grease duct. These components are all high maintenance items, which are in very difficult to access, above ceiling, locations. They are often overlooked during semi-annual inspections and maintenance is poor due to their out of sight location.

ABD designs have a more fundamental engineering flaw which cannot be ignored. In any exhaust fan system, a fan and blower are chosen based on given inputs: static pressure and design airflow (CFM). In a traditional system fans are provided with suitable margin and operational horsepower to meet the design point along the system curve, the red circle in Figure 3 as an example. Should actual static pressure vary slightly in the field, the fan will follow a system curve, as depicted by the dotted black line.

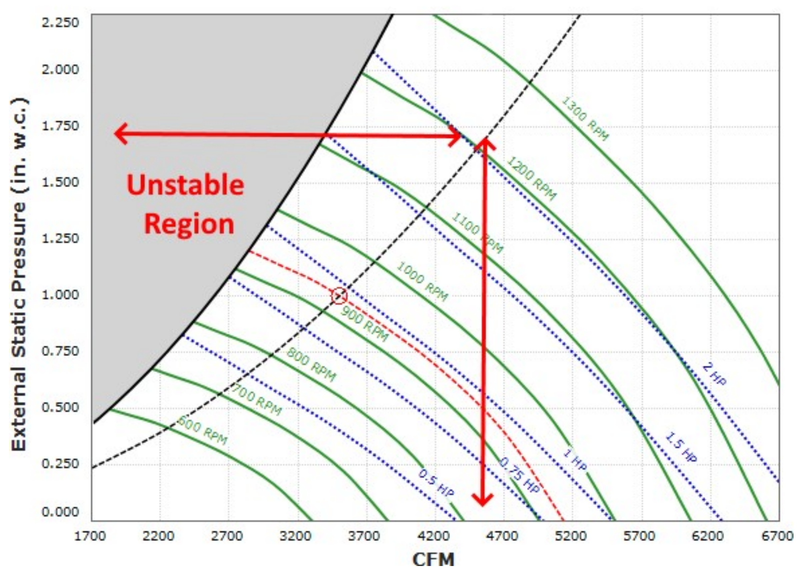

Figure 3 Typical Centrifugal Exhaust Fan Curve

In a system employing ABD technology, it is important to understand that the fan system curve is no longer applicable as the static pressure and CFM range is completely variable. As these systems operate on the premise of controlling airflow through closure of dampers, static pressures can spike while CFM is reduced, leading to operation in the gray area of the fan curve, often referred to as the unstable region.

Fan operation in the unstable region can lead to buffeting, inconsistent airflow through surging and stalling, excessive noise, and mechanical failure of duct and blower systems. Additionally, too low of modulation of airflow will result in operation in the main duct trunk line below the 500 FPM code minimum per NFPA 96. Low motor RPM can lead to premature motor failure from excessive heat as well.

Manufacturers of ABD systems attempt to develop algorithms to account for these variables, however like all complex products, it is inevitable that failures will occur in the design, installation, commissioning, and maintenance process. Test and Balance technicians are often unable to perform an accurate test and balance for such systems. Over time as pressure ports clog and dampers fail, operation of fans in the unstable region is inevitable.

One recent example of this was a major University Food Hall which utilized a combination of fourteen different exhaust ventilation hoods covered by two large grease exhaust fans. The ABD method was chosen as a solution by the design team. Unfortunately, as can be reviewed in the multi-million dollar publicly available lawsuit, the ABD system was never able to be commissioned properly even though the manufacturer of the system was subcontracted for commissioning. The system was operated for approximately three years. During this time, major damage was done to the exhaust grease duct from extreme static pressures created by the ABD system, buffeting of the exhaust fans through operation in the unstable region, or a combination thereof. The duct collapsed and numerous weld joints and seams failed from the abnormal operation[2]. These types of approaches, by design, utilize a large central exhaust duct which must be sized to handle the design peak airflow of multiple kitchens. Contractors are not generally familiar with the structural requirements of grease duct of this size, which require bracing and heavier gauge materials than traditional grease duct systems to avoid collapse under negative pressure. The use of factory built round grease ductwork is highly recommended to avoid this risk.

As a third and final engineering point, although manufacturers of ABD systems claim these systems allow for individual hood airflow control, the reality is that centralized exhaust fan systems must also simultaneously be supported by equally flexible replacement air systems. HVAC solutions for replacement air are even more limited in airflow range than UL-762 rated grease fans, as they have evaporative coils with specific airflow capabilities and/or heaters with limited operational bounds. When such systems are modulated to extremes, cooling coils freeze and heaters overheat or cycle excessively, leading to premature failure and/or major fluctuation in discharge air conditions. ABD system manufacturers typically only provide a simple 0-10v signal or similar and expect the building engineer to understand the complex sequence of operation and HVAC ramifications introduced by modulation of outdoor loads.

Real World Engineering Solutions:

When the Ideal System cannot be utilized, some practical real-world solutions can be employed through a combination of smart mechanical design and an upfront and honest discussion with clients about operational expectations.

Engineering Best Practices:

- Never utilize dampers in grease laden exhaust duct systems, particularly ABD type which rely on a pressure port which may become clogged.
- Limit combinations to 4 hoods or less. The ideal arrangement is 1 hood per fan, although it is understood in some venues up to 4 hoods may be combined as a compromise when duct routing is not otherwise practical.
- Utilize factory built and listed grease exhaust ductwork, which is tested to withstand the higher static pressures faced with complex duct runs, while allowing for lower overall static pressure due to smooth fittings and transitions.
- Avoid complex Sequences of Operation (SOO). In practice, multi-venue systems are in highly trafficked urban settings, and often are operating at or near full capacity most of the time. The sequence of operations should ideally incorporate a simple schedule and on/off operation with minimal modulation.
- Utilize Electronic Detection Kitchen Hood Fire Suppression Systems (CORE, TANK, or similar Electrical Wet Chemical approaches) which can be interlocked or not interlocked quickly through electronic means.
- Do not utilize mechanical fire suppression systems, which are not capable of being interlocked across multi-venue systems when sharing grease duct.
- Due to operational complexity and limited space for make up air duct systems, consider utilization of DOAS type technology for building HVAC, which allows for decoupling of HVAC from hood operation as required for comfort.
- Do not install HVAC returns in or around kitchens with grease exhaust hoods.

A practical implementation of the above principles, with a focus on simple and sustainable operation, will lead to a high-quality long-term outcome with the lowest possible initial equipment expenses.

References:
1. Stephen K. Melink. The Costs and Risks of Damper-based Controls in Kitchen Ventilation: Engineers Must Think in Terms of Total Safety and Optimal Energy Efficiency when Designing Kitchen Ventilation Systems of the Future. Melink Corp. Milford, Ohio: 2014. Accessed 04/08/2014.

2. Daily Hampshire Gazette, UMass lawsuit seeks nearly $3 million over alleged construction flaw, 12/2020, Accessed 12/19/2020, <https://www.gazettenet.com/UMass-files-$2-8-million-lawsuit-against-contractors-responsible-for-failed-Blue-Wall-ductwork-37603589>