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Split DX:
Make Sure It's the Right Choice

TVs, VCRs, DVDs … PCs, scanners, printers … automobiles, lawn mowers, golf balls … where to fish, which paint to apply, what fund to invest in …

Although they are dissimilar in nature and importance, the items in the preceding list hint at the plethora of products and services competing for our attention and our wallets. Choosing the "right" product or service is a matter of knowing the requirements and garnering enough information about the available options to compare their benefits and shortcomings. The larger the investment and the longer lived the product, the more likely we are to enlist the advice of an expert.

The Internet provides immediate access to a vast store of free information. But while the information is monetarily free, it can be time-consuming to find and incomplete in scope. Without sufficient understanding of the subject, it's likely that such "advice" will lead to a less-than-satisfactory outcome and/or unexpected expense … lending substance to the adage, "a little knowledge is a dangerous thing."

Informed decision-making

Expert advice in the HVAC industry, as in many other technical fields, frequently carries a cost. That cost may take the form of a separate consulting fee, or it may be part of the purchase price of the product or service. In either case, the purchaser rightfully expects to receive knowledgeable guidance that will allow him/her to make an informed decision.

When it comes to helping a client choose the "right" HVAC system, the expert advisor's responsibilities are to clearly outline the options and to present the consequences—good *and bad*—associated with each system choice. Furthermore, this information must be presented in terms that the recipient can understand and utilize to make an informed decision. The goal, after all, is to help the client obtain the system they *need* rather than the one they *think* that they want. Choosing and applying an HVAC system based on incomplete or misunderstood information carries considerable risk for unexpected expense and unhappy occupants.

Keys to successful application of split DX systems

The efficiency and reliability of a split air-conditioning system hinges largely on the piping that connects the refrigerant-condensing and air-handling sides of the system. Operational difficulties are inevitable if this interconnecting piping is improperly designed or installed, regardless of how carefully the equipment was selected and applied.

Interconnecting piping designs that successfully avoid these difficulties share several common traits:

- A simple, direct layout that reduces the amount of system refrigerant
- A refrigerant tube size that consistently returns oil to the compressors
- A refrigerant tube size that doesn't cause excessive pressure drops, which reduce compressor efficiency and capacity ●

Consider split DX (direct-expansion) air-conditioning systems—reputedly the least expensive HVAC system to install and often the only system considered in small commercial cooling applications (i.e., 120 tons or less). This preconception, coupled with the desire to minimize the initial cost of the project, can lead to "corner-cutting" that may ultimately hamper the system's ability to deliver the expected capacity, efficiency, and/or reliability. The net result is a system that costs *more*, not less, to own and operate.

Providing sound guidance about the appropriateness of a split DX air-conditioning system for a particular application requires a good understanding of that system's limitations. In other words, it's important to know which "corners" can be cut, which ones can't, and the consequences of "force-fitting" the system to the job at hand.

Avoid corner-cutting

Let's look at four examples of the "corner-cutting" that commonly occurs in applications of split DX systems. In each case, we've identified the inherent hazards and provided "expert advice" to help you determine whether a split DX system is the right choice for a particular application and, if so, to help you improve the odds for success.

Ambiguous bids. In situations where a split DX system is predetermined as the system choice, it's common to solicit separate bids for the condensing unit, air handler, controls, and installation. The obvious aim is to accept the least expensive quote for each component and service.

While this strategy achieves the bid goal, it does not assure a lowest *overall* first cost and may not deliver a system that provides the desired reliability and performance. Dividing the bid may force the purchaser to work with four different vendors—each one advocating their own products and manner of doing things. Competitive bidders seldom communicate with each other, so their lowest price quotes for each component are unlikely to include provisions for making the other parts of the system work. The risks are obvious: integration problems that lead to out-of-budget expense, and an uncoordinated system that isn't the most reliable, comfortable, or inexpensive.

Expert advice. You can mitigate these risks in one of three ways:

- Request a bid that explicitly addresses how the component will integrate with the rest of the HVAC system.
- Request a single bid for the *entire* split DX system rather than for individual components.
- Choose a central system, which can better tolerate deviations from the specification because the refrigerant circuit is factory-packaged.

Excessive distance between components. It's tempting to conclude that a DX system is the only answer when budget dollars are limited. But as the following true-life scenario illustrates, ignoring application constraints can create serious (and costly) problems later …

Scenario: An historic building must be air conditioned and the budget is tight. The historic significance of the building's façade precludes a rooftop unit, so a split DX system is chosen instead because it's perceived as less expensive than chilled water cooling. It also allows placement of the condensing unit on the far side of the parking lot, about 200 ft away from the air handler.

Acoustically, this decision makes sense: The sound-pressure level 200 ft from the unit is 26 dB less than it is at 10 ft from the unit.[1]

On the other hand, this arrangement places the interconnecting refrigerant piping underground. Underground pipe is easily contaminated by moisture and dirt during installation, and the cool subterranean temperatures encourage refrigerant migration. Either characteristic can easily interfere with proper operation and eventually shorten the service life of the system.

Underground pipe also is difficult to reach if problems arise. Although serviceability can be improved by installing the pipe in a chase that's open to the air and accessible through a grate, such provisions are seldom implemented properly because they add unwanted expense.

The fact that much of the refrigerant piping is underground isn't the only problem with this application. *The overall line length exceeds the manufacturer's recommendation, jeopardizing the reliability of the system.*

Hardware manufacturers limit the size and length of interconnecting refrigerant lines, in part, to limit the amount of refrigerant in the system. The "extra" charge that's needed to compensate for longer lines makes it

Refrigerant lines affect reliability

Manufacturers attempt to guard the reliability of DX split-system equipment by defining maximum line lengths and optimum pipe sizes. The limits they establish serve four underlying objectives:

- Assure that oil returns to the compressor
- Provide sufficient subcooling to maintain a continuous column of liquid refrigerant at the expansion valve
- Minimize capacity loss
- Minimize the amount of refrigerant in the system

One reason for the correlation between line length and reliability is the effect of ambient temperature on refrigerant density. As the ambient temperature changes, the liquid refrigerant occupies more or less space in the condenser–subcooler, which in turn affects the amounts of subcooling available at the condensing unit and the expansion valve. (See table below.)

Longer lines and the extra refrigerant they require make it difficult to get the right amount of refrigerant to the right place at the right time. Incorrect metering becomes more likely, and can lead to evaporator frosting, compressor slugging, and nuisance trips of the high- and low-pressure safety switches. ●

Effect of ambient (outdoor) temperature and refrigerant piping on subcooling

Ambient	Liquid-line tube size	System refrigerant charge	Subcooling At condensing unit	Subcooling Lost en route to evaporator	Subcooling At air handler 200 ft away
95°F (design)	7/8 in. OD	*X* lb	20°F	–5°F	15°F
	1-1/8 in. OD	*X* + 34 lb	20°F	–4°F	16°F
60°F (low load)	7/8 in. OD	(same as above)	14°F	–11°F	3°F
	1-1/8 in. OD		10°F	–10°F	0°F (flash gas)

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[1] This drop in sound-pressure level is typical of a point source situated on a flat plane within a free field (without obstructions), such as a parking lot or meadow.

more likely that a significant amount of refrigerant will collect in the wrong place at the wrong time. Increasing the line size—a misguided effort to make liquid refrigerant available at the expansion valve by reducing the pressure drop—makes matters even worse. (See the inset, "Refrigerant lines affect reliability.")

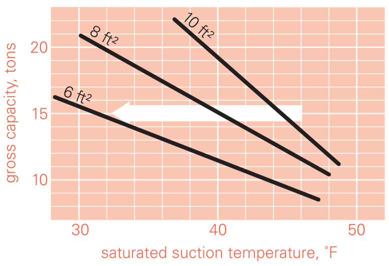
Expert advice. The constraints of the historic building in this example make it an ideal candidate for a chilled-water cooling system consisting of an air-cooled chiller and several small air handlers with chilled water coils. This solution preserves the acoustical and aesthetic advantages of siting the refrigeration equipment remotely. It also simplifies the design and improves reliability because the underground piping carries water, not refrigerant.

Missized air handler. It's common practice to base the selection of the air handler for a split DX system on a coil face velocity of 500 fpm and then to match coil capacity (with face area now limited by the size of the air-handler cabinet) with the load. With the trend toward applications that require less airflow per cooling ton, this sizing method leads to the selection of smaller air handlers. Providing the required cooling capacity with a smaller air handler demands colder suction temperatures (Figure 1).

As the cooling load decreases and/or the ambient temperature drops, the capacities of the compressor and evaporator balance at ever lower suction pressures and temperatures. At such conditions, system operation can become unstable and may eventually result in coil frosting and compressor flooding (Figure 2).

Expert advice. When choosing a DX air handler, it's critical to first determine a coil size that allows the evaporator and compressor capacities to balance at an appropriate suction temperature and pressure. You can then pick an air handler that fits the coil. This approach may appear to result in an oversized air handler, but it achieves a match of indoor and outdoor DX components that can operate more reliably at part-load conditions … enough to (perhaps) avoid the need for hot gas bypass.

Figure 1. Effect of coil face area on cooling capacity (6-row coil, 500 fpm face velocity)



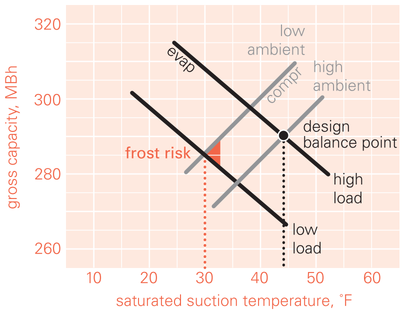
smaller coil face = lower balance points, more instability

By contrast, when choosing an air handler for a chilled water system, the initial objective is to pick the smallest possible air handler that won't cause water carryover.

Table 1 demonstrates an outcome of these sizing strategies: For comparable systems, the chilled-water air handler usually is smaller—and therefore less costly—than the DX air handler.

First cost vs. operating cost. It's common to add hot gas bypass (HGBP) to split DX systems as a means of stabilizing operation at low loads while preventing coil frosting. It may even be unavoidable in situations that require tight, uninterrupted thermal control—particularly if large amounts of outdoor air, widely varying loads, or excessive compressor on/off delays are involved. But, along with the operational problems associated with the increased refrigerant charge and additional piping, HGBP also trades the first-cost savings of selecting a smaller air handler for the extra energy cost to operate it over the life of the system.

Figure 2. Effect of ambient conditions and load on an air handler and condensing unit



With the U.S. facing its "most serious energy shortage since the oil embargoes of the 1970s,"[2] the total amount of power that a system consumes should be a concern for everyone. Economically, hot gas bypass increases the cost of the

Table 1. Comparison of air-handler selections for comparable DX and chilled water systems[a]

		DX cooling	Chilled water cooling
Cooling coil size		6 rows	6 rows
Supply airflow		4000 cfm	4000 cfm
Entering air temperature	High Low	83°F DB, 69°F WB 75°F DB, 63°F WB	83°F DB, 69°F WB 75°F DB, 63°F WB
Refrigerant suction temperature	High Low	**42.0°F** **34.7°F** (marginal)	— —
Entering water temperature		—	45°F
Chilled water ΔT		—	10°F
Coil face area		**12.3 ft²**	**9.6 ft²**

[a] Comparison is based on Trane equipment and a nominal DX cooling capacity of 20 tons.

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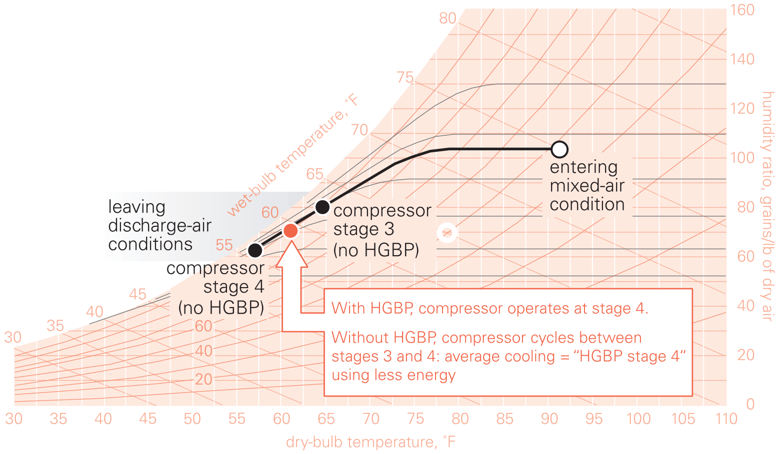
[2] National Energy Policy Development Group. *National Energy Policy.* In "Reliable, Affordable, and Environmentally Sound Energy for America's Future" [online]. May 2001 [cited 3 August 2004]. Available from Internet: <http://www.whitehouse.gov/energy/National-Energy-Policy.pdf>.

Figure 3. HGBP increases compressor energy consumption



With HGBP, compressor operates at stage 4.

Without HGBP, compressor cycles between stages 3 and 4: average cooling = "HGBP stage 4" using less energy

system and its installation; it also prevents the compressors from cycling off as the cooling load decreases. In effect, the system often operates at a compression stage that is one step higher than necessary (Figure 3). As a result, a split DX system with HGBP not only uses more energy but also is less efficient because the "extra" investment of energy does no useful cooling.

Expert advice. A chilled water system can better meet the same stringent requirements for precise, continuous thermal control … possibly using a *smaller* air handler and *without* hot gas bypass. When properly designed, the chilled water loop provides an effective buffer between system load and chiller capacity. Using the coil valves to regulate the available capacity as the compressor cycles allows the loop to serve as a "thermal flywheel." The key is to establish a loop time (water volume in loop/system flow rate) that equals the *greater* of two values: either the minimum "compressor off" time for the last stage of cooling, or the minimum loop time permitted by the chiller controller.

It's certainly true that a chilled water system introduces another energy-consuming component: the chilled water pump. Conducting a life-cycle cost analysis will help determine which system—chilled water or split DX with HGBP—will cost the least to operate over the life of the equipment, not just at the time of purchase.

Closing thoughts

Not every HVAC system is suitable for every building. Each indoor environment has a unique combination of requirements for ventilation, humidity and temperature control, service access, and available space. Against these considerations, the prospective buyer must weigh the relative importance of first cost, operating cost, reliability, and maintenance cost.

Hot gas bypass

When diminishing loads force a refrigeration system to operate at unstable conditions, compressor and evaporator capacities balance at ever lower suction pressures and temperatures. Unchecked, the eventual results are a frosted coil and (perhaps) a flooded compressor.

Hot gas bypass can stabilize the system balance point by diverting hot, high-pressure refrigerant vapor from the discharge line directly to the low-pressure side of the system. This keeps the compressor more fully loaded and allows the evaporator to satisfy the *sensible* part-load condition (but without addressing humidity control). Also, the diverted vapor raises the suction temperature, which prevents frost from forming.

Neither of these benefits will be realized without meticulous attention to the desired effect, component selection, and implementation. (See *Engineers Newsletter* volume 32-2, "Hot Gas Bypass: Blessing or Curse?" for more on this subject.) ●

Perhaps the most valuable advice we can provide is what system *we* would choose if the building were ours, along with clearly articulated reasons. Although the final decision rests with the purchaser, we can help assure that their decision is an informed one by presenting the facts—*all* of them—in a manner that they can understand and utilize. ●

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