ACTIVE BEAMS SELECTION CRITERIA
Transfer Efficiency

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In an active beam system, the performance of the beams has a significant impact on the overall system efficiency and occupant comfort. Since beams combine hydronic cooling and an air outlet, beams require the engineer to balance many relevant beam characteristics:

1. **Capacity**
2. **Configuration**
3. **Size (cost)**
4. **Quantity (cost)**
5. **Pressure drop (air and water)**
6. **Flow rate (air and water)**
7. **Primary air dry-bulb temperature**
8. **Primary air wet-bulb temperature**
9. **Chilled water supply temperature**
10. **Air pattern / throw**
11. **Noise**

The importance of all of these factors varies from job to job. Capacity and cost, for example, are always relevant and do necessarily influence the system design. One easy way to increase the capacity of the beam is to increase the primary air volume supplied to the beam. This has a two fold effect: first, it increases the cooling capacity of the supply air due to increased volume. Secondly, this increased air volume will induce more room air through the coil, increasing its heat in/output. The induction ratio, defined as the ratio of the induced mass air flow to that of the primary air coil, is a function of the nozzle size and the plenum pressure and is determined with the following equation:

$$induction\ ratio = \frac{Q_{induced\ air}}{Q_{primary\ air}}$$

Where the design must use caution, is in using this path for capacity increase too liberally. An increase in beam air flow also affects all other performance factors, most notably:

1. **Pressure drop (air)**
2. **Air pattern / throw**
3. **Noise**

Furthermore, it increases the percentage of the beam's performance that is attributed to the air system. This can cause control issues due to the number of annual hours that zones operate under part load. Considering that active beam systems are typically constant volume, this can pose a considerable risk of overcooling zones. A good measure for the overall performance of an active beam is known as the transfer efficiency, which is the ratio of total heat transferred by the coil per unit volume of primary air:

$$\eta = \frac{q_{sensible}}{Q_{primary\ air}}$$

Typical values for transfer efficiency vary by application type, but in general, the higher the efficiency, the more energy savings are available for a given system. The transfer efficiency is largely dependent on the air-side load fraction, the minimum ventilation requirement as a percentage of total load, and the sensible heat ratio, the sensible load as a percentage of the total load. The higher the sensible heat ratio, the smaller the beam nozzle can be. This metric allows the designer to evaluate how much coil capacity is available for a given primary air volume, thereby empowering them to make decisions on how much primary air is appropriate for the application.

In general, the selection of smaller nozzles results in higher plenum pressures for a fixed primary air flow rate. Larger nozzles will have a lower induction ratio, but will allow more primary air to be supplied, though at a lower transfer efficiency, as shown in **Figure 1.**
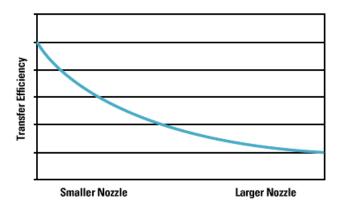

Figure 1: Transfer efficiency is reduced by increasing nozzle size.

Figure 2 shows the water-side performance of a typical beam vs. air flow. The curves correspond with various nozzle sizes increasing in diameter from left to right. The length of each curve is defined by standard operating pressures. It is noted from the graphs that the capacity of the beam increases as more air is supplied, though not in a linear fashion. Due to the amount of information provided, this chart is useful when selecting beams.
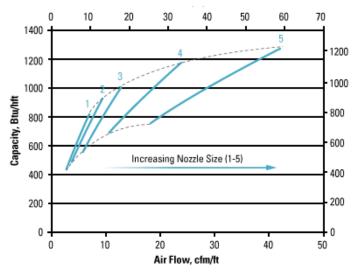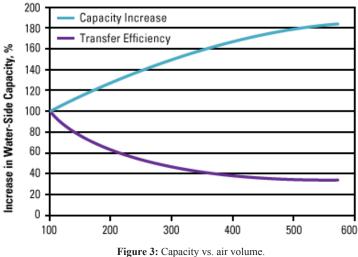

Figure 2: Capacity of a typical active beam v. primary air flow according to nozzle size.

Another way to show the same information is with the curves below. This graph shows how the increase in capacity is dependent on the air volume. As the nozzle size increases to provide a five-fold (500%) increase in air volume, only a 175% increase in the water-side capacity is realized, while the transfer efficiency reduces by 65%.

Figure 3: Capacity vs. air volume.

With the overall efficiency driven by the beam selection, it is critical that the beam meet the design intent of the job. An increase in the primary air volume will increase the capacity of the beam, to the detriment of the beam efficiency. While this may reduce the cost of the beam by reducing the length, so long as there is no penalty in draft, it will add to the cost of the primary air unit. The cost of the beam tends to be ~$5-$10 Btu/h, whereas the cost of an air handler can range from $2.5-$7 Btu/h, ignoring the cost of additional ductwork and large distribution equipment. This indicates that reducing the length of the beam may not achieve the cost savings sought.

In addition, this type of cost reduction approach can come at the cost of occupant comfort. By increasing the primary air volume, the overall discharge air from the beam is increased according to the induction ratio. For example, if the primary air volume is increased by 10 cfm and the induction ratio is 4:1, the actual increase in air volume from the beam is 50 cfm. If the length of the beam is reduced due to the increase in capacity, this additional air volume is discharged from a smaller slot length, increasing the throw and risk of draft, as well as noise levels.

In the end, selection of active beams by meeting the design requirements and the highest transfer efficiency possible under those conditions, as well as considering draft, will ensure that the design will be as efficient, comfortable and cost effective as possible.