stream and effecting uniform distribution over the entire face of the supply opening cannot be over-emphasized[2].

Dampers of special construction, as illustrated in Fig. 5, may be used to maintain a constant direction of blow, approximate distance of blow, and constant outlet velocity regardless of the damper's position. The capacity of dampers diagrammed as *A* and *B* will be roughly in proportion to the position of the operating lever and are particularly effective for cooling work with oversized grilles. The single leaf damper shown as *C* in Fig. 5 is objectionable in that it frequently results in a condition whereby two high velocity jets are created along the sides of the duct, or the air spills immediately downward on the occupants below the outlet.

Operation of Ceiling Outlets

The relationships presented for sidewall outlets will apply with the proper modification to the operation of ceiling outlets. With the ceiling outlets, the angle of distribution may be a full 360 deg. This extreme angle of distribution results in a high rate of induction and short blow,

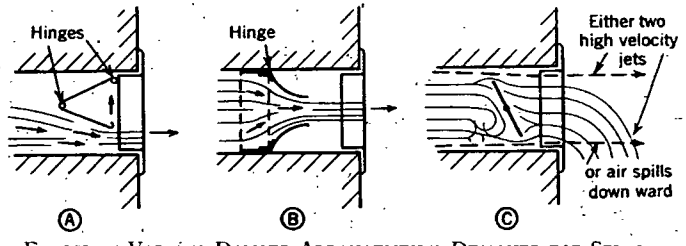

FIG. 5. EFFECT OF VARIOUS DAMPER ARRANGEMENTS DESIGNED FOR STRAIGHT BLOW

and also permits air to be introduced into a space satisfactorily at a relatively high temperature differential and high velocity. Ceiling outlets may handle greater quantities of air than a comparable sidewall outlet without the creation of excessive air motion. In contrast to wall outlets, the ceiling outlet does not necessarily have to be equipped with adjustable features, other than means to regulate air quantity. Frequently sections of ceiling outlets are blanked off to avoid having the air stream strike wall or column obstructions.

TYPES OF SUPPLY AND RETURN OPENINGS

Perforated Outlets. Due to the non-adjustability and small vane ratio of perforated sheet metal outlets, they have not met with favor as supply openings. They are useful primarily where directional air control is unnecessary, and for return air openings.

Vaned Outlets. Outlets equipped with both vertical and horizontal adjustable vanes are particularly suited to sidewall distribution. For proper control over the air flow, the vane ratio should be from 1 to 2. Outlets with non-adjustable vanes may be employed; however, they

[2]A.S.H.V.E. RESEARCH REPORT No. 1155—The Performance of Stack Heads, by D. W. Nelson, D. H. Krans and A. F. Tuthill (A.S.H.V.E. TRANSACTIONS, Vol. 46, 1940, p. 205). A.S.H.V.E. RESEARCH PAPER—Performance of Side Outlets on Horizontal Ducts, by D. W. Nelson and G. E. Smedberg (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, November, 1942, p. 686).

should only be used where the performance is not critical or can be adequately predicted.

Registers. Fixed vanes or perforated grilles equipped with a single blade damper are termed registers. They are primarily used for residential heating systems, where the outlet distribution is not critical and low cost is of importance.

Slotted Outlets. Slotted outlets essentially consist of either flat steel plates containing a number of long narrow slots or a single long narrow slot, with a free area of approximately 10 per cent. In order to give a good conversion from static pressure to velocity pressure, the sides of the slots are rounded to give a venturi effect. Due to their high aspect ratio, the slotted outlets have a greater induction effect than the comparable vaned outlets of equal area; thus, the throw of the slot is slightly less. They are primarily useful where an unobtrusive means of distribution is desired, and where it is desirable to submerge the outlets into the room decoration. Since these outlets offer greater induction at a given noise level, they are useful in obtaining proper air motion when otherwise limited by design.

Ejector Nozzles refer to outlets which operate at high static pressures, and which are constructed to give a high conversion from static in the duct to velocity pressure in the outlet, and have a high induction effect due to their high outlet velocity. The ejector is chiefly used for long throws and industrial process installations, such as drying, freezing, cooking, etc. Another type of ejector is sometimes referred to as a *louver nozzle* having a 45 to 90 deg elbow, which can be rotated similarly to a universal joint about an axis perpendicular to the surface to which it is fastened. These outlets give a considerable degree of adjustability and are, therefore, desirable for use in confined spaces where spot cooling is employed.

Ceiling Outlets. There are two general classifications of ceiling outlets, one the simple ceiling plaque, usually with limited induction effect, and the other a concentrically vaned ceiling outlet with high induction effect. Plaque outlets, although cheap and simple in construction, are difficult to control and are not generally satisfactory for comfort cooling where the entering air is more than 12 F below the room temperature. The vaned ceiling outlet with marked induction will distribute air uniformly over an entire half sphere. The induction effect is greatest in the direction of the axis of the outlet, and least in the plane perpendicular to the axis and located at the ceiling level. Thus the induction is greatest in the vertical direction where the least blow can be tolerated, and least in the horizontal plane at the ceiling where the greatest blow is both desired and permissible.

Perforated Ceilings. Such outlets consist of metal or composition board ceiling with small perforations through which air may be supplied to a room. The free area of the ceiling is about 10 to 15 per cent. The perforated ceiling can be designed to give a lower rate of room air motion for a given air supply than any other type of outlet. For this reason, the perforated ceiling is particularly applicable in installations requiring a low room air motion and having a high heat or ventilation load necessitating a high rate of air change.