DISCUSSION OF TYPES TESTED

Figs. 8 to 15 (pp. 144 to 151) show the design characteristics of the various types tested, in addition to Fig 4, appearing earlier. It is believed that most of the types in general use are covered. The conclusions reached regarding the relative merit of the various types are as follows:

1. The single-leaf damper in a round or rectangular duct is a thoroughly practical design and, if built with clearances not exceeding 0.25 per cent of the duct width as well as properly sized to the job so that its resistance at 30-deg opening is not less than 55 per cent of the total system resistance, a good flow characteristic is obtained. A damper of this size will have a low loss at the wide-open position. The characteristics of these dampers are shown in Figs. 4 and 8.

2. The addition of side stops to dampers of single-leaf construction, as shown in Fig. 10, decreases the leakage without materially affecting the flow characteristic, assuming that the damper is properly sized as outlined. If side stops are used and the damper is properly sized to the job, the side clearance may be increased from 0.25 per cent of the duct width to approximately 2 per cent, as shown in Fig. 11, without materially affecting the flow characteristic. However, if the damper is oversize for the job, the increased side clearance will have an adverse effect on the flow characteristic, as indicated by flow-characteristic curves 11, 12, and 13 in Fig. 11.

3. A streamlined damper blade, as shown in Fig. 9, reduces the pressure loss at the wide-open position slightly, but not enough to be of any great importance. The flow characteristic of this design is not materially different from the flat-blade louver, and either will give good results if properly sized. The particular model tested had somewhat greater clearance than other types investigated, since it was felt that this damper could not be held to the same manufacturing tolerances. The leakage at low rates is therefore correspondingly higher. Side stops on this type of damper would reduce this leakage without materially affecting the flow characteristic.

4. Multiple-leaf-louver dampers, of the types shown in Figs. 12 and 13, give good regulating characteristics although it is much easier to obtain a good regulating characteristic with the damper having dividing partitions between the louvers than with the type which does not have the dividing partition. To obtain an equivalent flow characteristic, the damper without the dividing partition must be appreciably smaller, which may in some cases result in increased draft loss in the wide-open position. The characteristics of the model with the dividing partition could be improved by the use of side stops, which would reduce the leakage in the closed position. If these side stops were added, the flow characteristics would be similar to those in Fig. 10.

Butterfly dampers having cast frames and cast butterflies, as shown in Fig. 14, have a very satisfactory flow characteristic if properly sized to the job. These units can usually be made to close quite tightly in view of the rigidity of the frame and of the butterfly.

Radial-vane-type dampers, of the type shown in Fig. 15, will give good flow characteristics if properly sized, though most dampers of this type are oversize, which result in a very poor flow characteristic. If the damper is made small enough to obtain a reasonably straight flow characteristic, there is likely to be some pressure loss at the wide-open position. This type of damper has its maximum effective opening at about 65-deg travel, so that there is no occasion to use greater travel than this in effect to increase effective openings. The vane can be made relatively tight closing if properly built and if arranged to overlap slightly in the closed position. From the standpoint of flow characteristic alone, this type of damper is not as desirable as the other types described but, since it is used primarily for the purpose of directing the gas flow into the inlet of the fan, the advantages gained thereby probably offset the disadvantages as a regulating device. It would appear that, with proper attention to the sizing of the fan inlet and thus the vanes, a reasonably good flow characteristic could be obtained without sacrificing pressure loss. One difficulty, of course, is the necessity for using different-size fan inlets for each installation.

A general conclusion is reached that most of the difficulties with dampers are due entirely to a lack of proper selection of size for each application, principally because no information was available to the designer. It is hoped that this work will stimulate some interest in this matter and lead others to make similar investigations and suggestions for improvement of this device which is so universally used.

Discussion

C. B. Arnold. In the past, many control systems have undoubtedly proved to be only mediocre, not because the control regulators were inadequate but because the pieces of equipment controlled, such as dampers and the like, have had characteristics which did not lend themselves to satisfactory control, thus placing an undue requirement on the regulators. This fact, of course, has long been recognized by engineers and efforts have been made to correct the situation. However, it is felt that, in most cases, interest in the problem waned as soon as a reasonable improvement of a particular situation had been realized.

For ideal results, equal incremental movements of damper actuators should render equal incremental changes in flow through the dampers. Practically, however, this degree of refinement is not frequently necessary. It is necessary, however, that the size of a damper be suited to the particular conditions for which it is designed.

Discussion continued on page 152.
intended, otherwise not even a close approximation of this ideal will be had. It is felt, therefore, that the authors have offered a very useful contribution by outlining a method of determining damper size so that it can be designed correctly, prior to its installation.

After the proper size of a damper has been ascertained, the further refinements relative to the connecting means between the damper and its power actuator should be given consideration. The arrangement mentioned by the authors, whereby equal increments of actuator movement produce small incremental movements of the damper near the closed position and, larger incremental movements near the open position, can be used to advantage in many cases. The merits of such an arrangement are as follows:

1. Actuator movement bears a closer relationship to flow through the damper.
2. Greater mechanical advantage is available when the damper is near the closed position, and frequently more force is required to operate the damper in this position.
3. Because of the additional mechanical advantage where it is most needed, as mentioned, smaller power actuators may be employed.

Granted that the size of a damper has been properly selected and that means of connecting the damper to the actuator have been satisfactorily arranged, there is still one other factor which may cause unsatisfactory results. This factor is damper unbalance. True, as the authors have stated, the torque-requirement characteristics of dampers are quite unpredictable, because of the unpredictable flow pattern ahead of and leaving the dampers. It is felt, however, that this unsatisfactory condition which frequently prevails should not be treated too lightly. One of the greatest causes of damper unbalance is the reduction of pressure, brought about by the increased velocity of air or gas between the damper leaves and between the dampers and their respective sealing strips, when the dampers are in the nearly closed position. If there is considerable overlap of one damper over another or of the sealing strips over the dampers, extreme forces are required to open them, and they tend to snap shut when approaching the closed position. If this unbalanced force were to change but gradually and always in the same direction, no serious consequence would result. However, in many cases, the unbalanced forces sometimes suddenly decrease or actually reverse in direction, as the dampers move through some critical point. These changes of force required to operate the damper cause overtravel in damper movement on either side of the critical point, due to lost motion or yield in the linkage, and are bound to produce a hunting condition which no regulator can stabilize.

The writer has had some experience with dampers which had these unsatisfactory unbalance characteristics and was able to produce a satisfactory improvement of the characteristics on two-leaf dampers by providing unequal damper areas on either side of the damper shafts. This caused a counter-unbalanced force sufficient to cancel out a major part of the unbalanced force which originally prevailed. It is felt, therefore, that further study of this condition would be beneficial and might reveal some general rules and useful techniques which would insure at least an improvement of the condition and indicate some of the pitfalls to be avoided.

F. C. Smith. The writer has been greatly interested in the authors' comments with regard to unbalance caused by overlap of the damper on sealing strips. Further comment by the authors concerning sealing strips would be greatly appreciated. For instance, what has been done along the lines of making use of spring-type strips somewhat comparable to the principles employed in ordinary building weather stripping? It appears to me that use of such sealing might greatly decrease the unbalanced condition which has been discussed.

C. L. Myers. The authors have selected a subject that well deserves attention. The annual loss resulting from faulty dampers would be startling if there were any reliable figures available to establish it. Some index may be taken from the fact that our records indicate an average efficiency increase of 5.7 per cent for one group of installations after the dampers had been replaced; this figure does not take into account the item of equipment maintenance which is frequently effected.

The authors have defined the ideal flow characteristic, as shown in Fig. 16 of this discussion, and suggest that dampers be reduced in size to a point where the ratio of damper resistance to total system resistance is not less than 55 per cent at 30-deg opening. In order to visualize this recommendation, Fig. 16 includes the several flow curves corresponding to 55 per cent resistance and also, for comparison, curve 1 from Fig. 4 and curve 12 from Fig. 9 of the paper, to indicate the limits to which the curves can be moved by extremes of damper-size adjustment. The former corresponds to 68 per cent resistance at 30-deg opening and the latter, to 0 per cent resistance at 30-deg opening.

It is suggested that designers may find some difficulty in reducing damper sizes to those recommended without encountering problems of flow distribution in the system. Another problem may be found in that the indicated damper area, when divided by the necessary width, may result in a small height. Such dampers are more difficult to build to close clearances due to sag.
The increased leakage, resulting from the larger clearance necessary, has an adverse effect on the damper characteristic. These problems suggest a search for additional approaches.

The authors have made the alternative suggestion that the linkage, as shown in Fig. 1, be employed, but point out that such linkage must be maintained in perfect condition in order to obtain its benefits. They have also suggested that, in the case of multiple-leaf dampers with partitions, one or more sections can be blocked off. This procedure would seem to introduce distribution problems. Neither course will affect materially the leakage problem at the lower end of the curve.

Fig. 17 of this discussion shows curves 5 from Fig. 9 of the paper. Superimposed is an hypothetical "modified flow," which more nearly conforms to the desirable straight line and the "modified damper resistance" which would be required to produce such a flow curve. Area $D$ indicates the need for less resistance which would be accomplished by more damper area. Area $E$ indicates the need for more resistance or less damper area. This leads to the conclusion that the answer may be found in modification of the shape of the damper opening rather than rectilinear reduction of its size alone.

Such an approach to the problem is illustrated by Fig. 18 of this discussion. Obviously, the V-porting shown can be extended to provide any desired shape in the resistance curve, and thus any desired flow characteristic. Since there is no clearance between the moving part of the damper and its sealing strips, the leakage problem indicated by area $E$ is eliminated, regardless of the size of the damper. Another thought involves the elimination of inclined planes in the path of flow, thus reducing turbulence and resistance. This is desirable in area $D$ and modifies the amount of shaping necessary to obtain the desired result.

The authors have pointed out several other problems as follows:

1. Need for increased clearance for higher temperatures.
2. Power requirements.
4. Shafts, bearings, and seals.
5. Leakage.

Examination of the design, illustrated by Fig. 18, establishes that large operating clearance is provided for the moving parts without introducing leakage. It also shows that ample strength to prevent sag in wide dampers is provided without introducing a large mass in the path of flow, that the weight to be supported is less and, further, that any sag which may develop does not require clearance effecting leakage. Since large operating clearance is provided, binding is eliminated. The problem of dynamic balance disappears automatically. Shafts can be made large in proportion to the weight supported. Bearings are in a favorable location more or less away from the flow and in a position which does not tend to distort to cause misalignment. Good seals should be provided in any case. These facts all add up to modest power requirements.

Leakage is a problem of a magnitude but little appreciated. Most dampers in service have been warped to an extent that the leakage has been materially increased from what it was when they were originally installed and the original leakage is usually considerable. The adverse effect of leakage on the flow characteristic is well illustrated by the several curves in the paper. Leakage of cold air into the breeching from cold boilers reduces available draft and thus capacity. Leakage of isolation dampers results in poor and even dangerous working conditions for maintenance crews. Elimination of leakage increases the range of efficient output. Leakage in an uptake damper results in a considerable loss of heat during banking periods. Leakage of air past a damper, controlling flow to a fuel bed, results in increased banking losses. Leakage in a by-pass damper permits heat to short-circuit the economizer or air heater. Leakage past an uptake damper to a breeching leading to an economizer reduces the temperature and increases the volume of gas passing through the
The economizer, thus reducing its heat-absorbing efficiency and, passing on to the induced-draft fan, increases the power consumption, sometimes overloading the fan to the extent that full capacity is not attainable. Some dampers are so located that leakage results in recirculation, which leads to increased fan power and loss of capacity. Leakage, in some cases associated with air heaters or economizers, results in corrosion problems.

The authors have made a splendid contribution to a subject that can lead to very real improvement in the art of steam generation, conservation of fuel, and substantial economies.

**Authors’ Closure**

The discussion by Mr. Arnold is appreciated as it emphasizes the need for greater care in the selection of dampers and the mechanisms for operating them. An important point brought out by Mr. Arnold is the fact that proper design of the linkage between the damper and the operating mechanism not only improves the flow characteristic, but reduces the torque requirements of the operating mechanism. We agree that the matter of damper unbalance requires further study, but this is beyond the scope of this paper. It is hoped that studies can be made later which will throw some additional light on this matter.

To answer Mr. Smith’s question; the authors have had some experience with the use of sealing strips for decreasing the leakage in the closed position. We have used both weather-stripping construction and strips of flexible materials, such as asbestos tape, and find that satisfactory results can be obtained. The principal difficulty is the added cost, inasmuch as these strips must be fitted in the field, if satisfactory results are to be obtained. This adds considerably to the cost of the damper. The leakage on dampers of simple design, if properly sized, is not generally serious, and sufficient tightness can usually be obtained by the addition of metal stops on the damper frame.

The design of damper offered by Mr. Myers is interesting and unique. It offers the possibility of providing any desired area and flow characteristic. However, if suitable results are to be obtained, the area characteristic of this damper must be determined and a corresponding port-shape in the damper must be provided. It is for the purchaser to decide whether the desirable flow characteristic can be accomplished more easily and at less cost in this type of damper than in one of conventional design.

Mr. Myers is quite justified in pointing out that the damper which is properly sized does not give a straight-line relation between motion and flow increase. However, it will be noted that the average of the various curves, shown in Fig. 17 of his discussion, which incidentally do not represent the best that can be obtained for each damper type, still shows less than a $2'/s$ to $1$ change in slope over the effective range of travel. By arranging the linkage between the operating mechanism and the damper to use only the effective portion of damper travel, which in this case is approximately 70 deg, and incorporating some angularity in the linkage, a very nearly uniform slope could be obtained. In most cases no difficulty would be encountered with dampers having a flow characteristic similar to the average of these curves with or without angularity in the linkage, as the change in slope is not sufficient to present any regulation problems.