



ESDU TECHNICAL MEMORANDUM

Effects of truncation on diffuser performance

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ESDU TECHNICAL MEMORANDA

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THE PREPARATION OF THIS TECHNICAL MEMORANDUM

The development and preparation of this Technical Memorandum were undertaken by

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1. INTRODUCTION

1.1 Notation

A cross-sectional area of duct

C_{pr} static pressure recovery coefficient

D_h equivalent diameter of duct

L axial length of diffuser

R radius of circular duct

η diffuser effectiveness, $C_{pr} / 1 - \left[\frac{A_1}{A_2} \right]^2$

θ diffuser wall angle

Suffixes and superscripts

1 diffuser entry plane

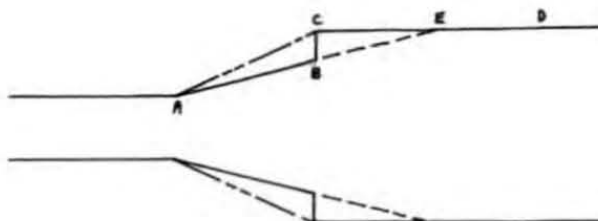
2 downstream duct

t applicable to truncated diffuser/tailpipe combination

' at or up to exit plane of tapered section

1.2 What and Why?

A truncated (or cropped) diffuser is one in which part of the area increase is achieved by a sudden enlargement of area as shown by the geometry ABCD in Sketch (i). This may be regarded as a derivative of the full length



Sketch (i)

diffuser AED. It is also of interest to compare it with the wider-angled diffuser ACD which has the same length.

The general philosophy behind the idea of truncation is that, if separation occurs anyway in a diffuser, cutting off the end and using a sudden enlargement of area to maintain the overall area ratio is not likely to have seriously adverse effects. On the credit side, a shorter overall diffuser might result together with a more uniform downstream flow resulting from the stable, distributed separation at the enlargement.

2. DATA AVAILABLE

The sources of data available are summarised in Table I. Most of the data are from References 5 and 7 and most are for conical diffusers with $\theta = 5^\circ$.

Two prediction methods are given in the literature, Gibson in Reference 1 and Henderson in Reference 2. Gibson suggests that the overall loss is the sum of the loss in a diffuser plus tailpipe of the area ratio at truncation and the loss in the sudden enlargement. Henderson suggests that the overall loss is the sum of the loss in the untruncated diffuser and the loss in the sudden enlargement. Figure 1 compares the two predictions on the basis of the predicted change in diffuser effectiveness for an overall area ratio of 4 and a wall angle of 5° . Gibson's prediction is shown using both his own C_{pr} values and values from ESD Item No. 73024. The essential difference between the predictions is that Gibson's suggests the possibility that a truncated diffuser may give a slightly better effectiveness than an untruncated one. However, using the ESDU C_{pr} values, there is quite close agreement between the two predictions over much of the range of truncation lengths.

Both predictions appear to include the tailpipe effect twice. It would seem more logical to take the sum of a diffuser alone up to the truncation point plus a sudden enlargement. However, Figure 2 compares such a prediction (both with and without allowance for the entry conditions to the sudden enlargements) with experimental data from Reference 3 from which it can be seen that the Gibson and Henderson predictions are much better. Evidently the sudden enlargement exit interacts with the diffuser section as a result of its close proximity.

Figures 3, 4 and 5 compare the predictions with experimental data from References 6, 2 and 5. The agreement in Figure 4 and 5 which maintain constant wall angle with reducing cone length is fair. The case of constant cone length and reducing wall angle is less well predicted although the trend of improved pressure recovery with reducing angle is shown in both cases.

Reference 4 gives values of 'resistance_coefficient' for truncated diffusers of various cross-sections but only for what is claimed to be the optimum wall angle. These are based on so-called approximate calculation formulas but the original references are not available in order to check the derivation. The optimum angles seem rather wide-ranging instead of being located around the maximum recovery values of the diffusing sections and therefore this source has not been used.

Some information on recovery lengths and downstream flow conditions is given in References 5 and 7. This is discussed in the next Section.

3. DISCUSSION

3.1 Pressure Recovery

Most of the data available are for $\phi = 5^\circ$ conical diffusers. Since these generally operate without appreciable separation and have good pressure recovery it is unlikely that truncation will give any improvement. Indeed, since separation is being introduced the performance is likely to be reduced. This is in accord with the experimental data. The only data which could be interpreted as showing some improvement are those for an area ratio of 9.8 for which an untruncated diffuser with $\phi = 5^\circ$ will operate with separated flow.

The conclusions which may be drawn from the comparisons of predictions with experimental data seems to be that either of the predictions may be used to give a general picture of the effects of truncation. The agreement with experimental data is not good but variations of at least the same magnitude can often be found in the data for simple diffusers. One point which should be noted is that the ESDU data used in the predictions are mean values for tailpipe lengths of around $4D_{h2}$ whereas most of the experimental values are measured at the maximum recovery point. The differences will be small relative to the uncertainty of the predictions.

In Figures 6A to 6D the Gibson type prediction has been used to explore the effect of truncation on a wider range of diffuser geometries. Some show quite large improvements in pressure recovery with truncation. As might be expected these are geometries in the separated flow regimes and the optimum truncation is roughly that which places the geometry of the truncated cone below the significant separation band 'a'a' in Figure 1 of ESD Item No. 73024.

The basic truncation effect (shortening of the cone) is shown by the dashed lines on Figures 6A and 6B. The solid lines show the effect of reducing the wall angle while maintaining the same overall length, i.e. going from geometry ACD to ABCD in Sketch (i). Again the predictions suggest that diffusers of higher area ratios and wall angles, which would operate with separated flow, can be improved by reducing the wall angle. Again, however, if the untruncated diffuser has a geometry which places it in the attached flow regime, truncation reduces the pressure recovery.

On the available evidence it seems reasonable to suggest that if the basic geometrical requirements require a diffuser which will operate with a significant degree of separated flow then an improved pressure recovery may be obtained by using a cone of reduced length or angle such that the cone is near optimum and completing the area change with a sudden enlargement. No improvement can be expected if the original diffuser is near optimum or operates in the attached flow regime. As a useful indication of the pressure recovery obtained we can approximate

$$C_{prt} = C_{pr \text{ diffuser section}} + (A_1/A')^2 C_{pr \text{ enlargement}}$$

3.2 Diffuser Length

It is evident that truncation will reduce the length of a diffuser but it is the overall length including the tailpipe which is important if maximum recovery is to be obtained. Duggins (Reference 5) measured the overall recovery length and concluded tentatively that this was reduced by the amount by which the diffuser was shortened, i.e. the required tailpipe length was unchanged. Measurements made in Reference 7 were said not to have conclusively supported this. Few data are available on tailpipe lengths required for full pressure recovery but the general trend is towards greater lengths as the wall angle and area ratio increase. It is possible therefore that a diffuser/sudden enlargement combination will require a longer tailpipe than a diffuser alone.

The ESDU data present in the Data Items are averaged out for a range of different tailpipe measurement conditions and assume a constant length of some $4D_{h2}$ to $8D_{h2}$ which should be more than adequate. Thus it is reasonable that if the design criterion ($L_d \approx 4D_{h2}$) has been adopted the overall length of the truncated diffuser may be assumed shorter than the untruncated diffuser by the reduction in cone length. It should be noted that except for θ less than about 7° it is not possible to obtain a $4D_{h2}$ tailpipe by cutting back a cone with free discharge.