

MODIFICATION OF TRACTION MOTOR BLOWER DUCTS

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Synopsis: *Presently WAG-7 locomotives are being provided with 'crew friendly' driving cabins which are wider than those in earlier locomotives. Modification of one of the air duct becomes necessary in the revised layout. This paper examines the suitability of duct modification and concludes that air delivery to traction motors is not adversely affected by it. The paper re establishes the importance of setting the deflector accurately.*

1.0 INTRODUCTION

1.1 BHEL started manufacture of WAG-7 locomotives in 2008. The locomotives were expected to be provided with crew friendly cabins. As a part of this requirement, the cabin has to be widened. This calls for pushing back the AC-2 panel into the machine room by about 500 mm from its position in conventional locomotives. In this position the conventional structure of AC-2 panel fouls with the traction motor blower duct on cab-2 side whereas there is no such impact on the cab-1 side. CLW modified the structure of AC-2 panel positioning the duct under it. Since BHEL had already advanced with manufacture of AC-2 panel, implementation of this modification would have upset the production schedule.

Under these circumstances a modification to duct was contemplated so that conventional AC-2 panel could be accommodated. Incidentally this was borne out of the experience at Locomotive Workshop Dahod (WR) where in rehabilitation of WAG-5 locomotives a similar requirement is being met. Initially this modification was permitted by RDSO for 3 locomotives. Later based on the results of air flow measurements, the approval was extended to 10 locomotives and now BHEL has been allowed to implement this modification on regular basis.

1.2 Need for meeting the production schedules apart, this modification offers following advantages for performance of locomotives.

- a. *The structure of AC-2 panel remains strong unlike the modified version which has a weak foundation.*
- b. *The delicate relays and contactors are saved from exposure to vibrations induced by the duct carrying air.*
- c. *The access to AC-2 panel for maintenance improves.*

2.0 THE MODIFICATION

The route of the duct was changed as shown in Fig-1. The portion of duct supplying to TM-6 is lowered in a slant manner instead of the inverted 'L' shape in original arrangement. Mean length of the duct reduces but an additional bend is introduced. While this makes the required space for the AC-2 panel, the issue remains to be examined if there is any adverse impact on the air supply to:

- a. the TM-6 compared to the remaining two traction motors or motors fed by TM blower-2
- b. the traction motors fed by TM blower-2 in comparison to those fed by TM blower-1.



Modified



Unmodified

Fig-1 Modification to the duct arrangement

3.0 ANALYSIS

The air delivery system can be modeled as shown in Fig-2.

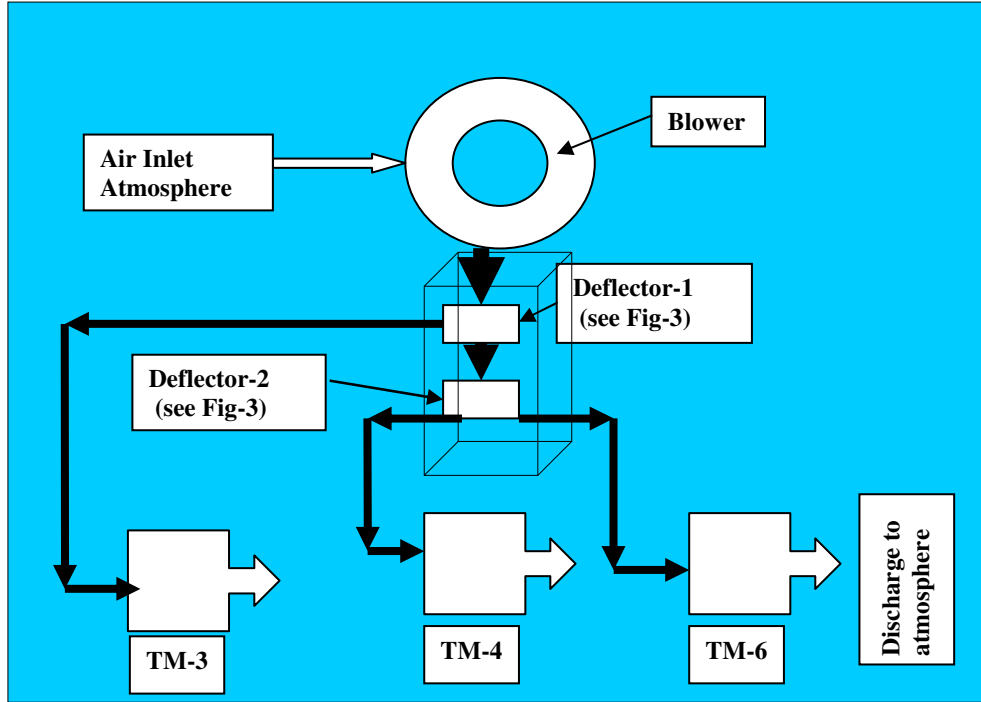


Fig-2 Model Of Duct Arrangement

The loss of pressure as the air flows through various parts of the duct to reach the traction motors 4, 5 & 6 has been theoretically estimated at Annexure-I. The loss is defined as under:

- a. **Major Loss** This loss arises due to resistance to flow of air caused by friction along the walls of duct.
- b. **Minor Loss** This includes losses arising out of the geometrical features like
 - **Bends**
 - **Expansions and contractions**
 - **Connections**

Following table gives summary of the losses estimated in the air paths leading to the three traction motors served by the duct in its original version. Also the losses in modified version are tabulated alongside.

Table-1

Pressure Loss	In the path of air through the duct leading to			
	TM-4	TM-5	TM-6 (unmodified)	TM-6 (Modified)
Major	10.3	7.6	4.6	4.4
Minor	67.1	81.1	64.2	77.9
Total	77.4	88.7	68.8	82.3

It is important to take note of the fact that the total head developed by the traction motor blower is about 308 mm WG according to the specification as well as the type test report. The head at the entry to traction motor is 190-210 mm WG as evidenced actual measurements on the locomotives manufactured recently. Thus the drop of head in the ducting should be 100-118 mm WG in the duct system as a whole. The theoretical resistance offered by the ducting is tabulated above. This is in agreement with the estimation through other sources as described in the preceding lines if the role of deflectors is taken into account. There are two deflectors which have to be set to equalize the flow of air to all three traction motors. It may be seen that the resistance offered by different paths is not identical or even close to one another. By setting the deflectors to appropriate positions, equalization of air flow is achieved. It can be said that the deflector will add some resistance to some paths so that all paths become similar. It may be borne in mind that designed or even the actual air supply may be more than that demanded by the specification of traction motor.



Fig-3 Arrangement of Deflectors to Distribute the Air

4.0 PRACTICAL VERIFICATION

The air flow measurements on two locomotives yielded the following results. It may be borne in mind that the measurements were conducted with external electric supply (415 Volts 50c/s) to both TM blowers. MVMT speed was for the specified condition was 2906 rpm. But during the rather long period of testing the variations in supply conditions- particularly the frequency- may have inevitably affected the results but within tolerable limits.

Table-2

(All figures in m^3/min at free end)

Loco No	Fed from MVMT-1			Total	Fed from MVMT-2			Total
	TM-1	TM-2	TM-3		TM-4	TM-5	TM-6	
24502	135.6	135.6	134.5	405.7	134.3	133.9	141.6	409.8
24503	140.7	145.9	142.4	429.0	153.9	153.8	148.2	456.09

It may be noted that the duct arrangement is as in original locomotive for TM blower-1 whereas it is modified TM blower-2.

- a) *The air flow to all six traction motors is nearly uniform.*
- b) *The total air delivery by each blower remains by and large equal.*

Further in one locomotive air flow was measured by creating a suitable obstruction to develop head equivalent to that in traction motor under worst condition of choking. Even *though flow measurement becomes problematic in such configuration due the turbulence caused by the obstruction*, following results were obtained.

Table-3

Loco No	Fed from TM blower-1			Total	Fed from TM blower-2			Total
	TM-1	TM-2	TM-3		TM-4	TM-5	TM-6	
24501								
Head (mm WG)	243	250	266		243	240	236	
Flow (m^3/min)	101.9	103.4	102.8	308.1	103.8	102.1	104.5	310.4

The measured value of flow differs from that measured in the type test ($285 \text{ m}^3/\text{min}$) by 9%. This is explainable due to two factors: measurement error caused by turbulence in flow and changed power supply.

Once again the inferences drawn in case of free flow measurement drawn above are supported.

4.1 Performance in Locomotive after Implementation of the Modification

As a regular practice, the pressure in all the commutator chambers is measured as per SMI/39 and recorded. The observation of static head in the commutator chambers of some locomotives is tabulated below.

Table-4

Locomotive No.	mm WG					
	TM1	TM2	TM3	TM4	TM5	TM6
24501	210	210	220	200	200	190
24502	210	210	210	200	200	200
24503	200	240	210	240	220	200
24504	200	200	200	220	230	220
24506	200	220	210	220	220	200
24507	200	210	200	220	200	220
24508	200	210	220	220	230	210
24510	220	220	200	210	240	210
24511	220	240	240	220	230	240
24512	230	230	230	220	220	220
24513	220	250	230	220	220	230
24514	200	210	205	205	240	245
24515	210	210	220	200	220	200
24516	210	210	220	200	220	200
24517	210	210	220	200	220	200
24518	200	210	210	200	220	200
24519	200	200	220	200	220	200
24520	210	200	205	210	205	215
24521	190	230	190	220	220	200

The above table further confirms the uniformity of cooling air across all six motors three of which are fed from blower-1 with original design of duct and the remaining three fed from the blower-2 with modified duct system. Indeed it was observed repeatedly that setting the position of deflectors had a very strong impact on the pressure achieved at the entry to different traction motors.

5.0 CONCLUSION

Theoretically the duct constitutes a third of the overall resistance in the total circuit as shown in the analysis. As also the proposed alteration does not appreciably change even the minor part of total resistance contributed by the duct. The modification has no appreciable affect whatsoever on the distribution of cooling air. The traction motors continue to receive appropriate delivery of air at the required pressure.

It is, therefore, evident from the practical measurements as well as theoretical analysis that modification carried out in locomotives at BHEL Jhansi has not in any way affected the distribution of air to traction motors. Therefore the benefits of retaining a sturdy structure of AC-2 panel can be enjoyed without sacrificing the performance of air delivery system

The distributing dampers must be accurately adjusted to achieve the equalization and locked in that position by tack welding to avoid any accidental change in distribution of cooling air. During experiments it was observed that air distribution was most sensitive to the position of dampers. Indeed developing a better arrangement for adjusting and locating these dampers can be taken up as a further project.

6.0 ACKNOWLEDGEMENT

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Calculation of Change in Loss of Head Due to Modification of Duct in

WAG-7 Loco

The pressure loss is divided in two parts

(1) Major Loss

The pressure loss in ducts depends on the flow velocity, duct length, duct diameter, and a friction factor based on the roughness of the duct, and whether the flow is turbulent or laminar - the Reynolds Number of the flow. The pressure loss in a tube or duct due to friction, major loss, can be expressed as:

$$\text{Pr. Loss} = \lambda (L / D_h) (\rho v^2 / 2) \quad \text{D'Arcy-Weisbach Equation}$$

Where

Pr. Loss = pressure loss (N/m^2)

λ = friction coefficient (depends on type of flow denoted by Reynolds's no. - **Re**)

L = length of duct or pipe (m)

D_h = hydraulic diameter (m)

ρ = density (density of air $\rho = 1.2 \text{ kg/m}^3$)

v = velocity

A. Calculation of Hydraulic Diameter of Rectangular Ducts (D_h)

$$D_h = 4 A / p$$

Where

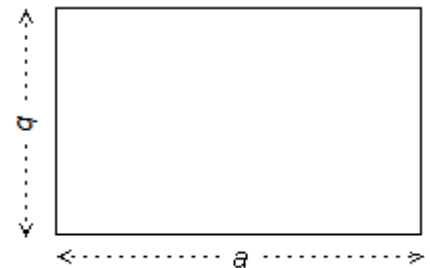
D_h = hydraulic diameter (m)

A = area section of the duct (m^2)

p = wetted perimeter of the duct

Hydraulic diameter of rectangular duct

$$\begin{aligned} D_h &= 4 a b / (2 (a + b)) \\ &= 2 a b / (a + b) \end{aligned}$$



B. Determination of Friction Coefficient (λ):

For turbulent flow the friction coefficient depends on the Reynolds Number and the roughness of the duct or pipe wall. On functional form this can be expressed as:

$$\lambda = f(Re, k / D_h)$$

Where

k = relative roughness of tube or duct wall (mm)

k / D_h = the roughness ratio

With the **Moody diagram (annexure-1 at page-3)**, the friction coefficient can be read corresponding to the **Reynolds Number** and the **roughness ratio**

(i) Type of Flow (Reynolds No. - Re)

$$Re = D_h V / J$$

Where

v = velocity

J = Kinematic Viscosity

J = (Absolute viscosity/ Density of air)

$$= (1.79 \times 10^{-5}) / 1.23$$

$$= 15.11 \times 10^{-6}$$

(i) Roughness Ratio

For this duct's material **relative roughness** can be taken as **0.045×10^{-3} m**

$$\text{Roughness Ratio} = k / D_h = 0.045 \times 10^{-3} / D_h$$

Major loss

Duct Leading to	(N/M ²)	mm of W G
TM 4	101.3	10.33
TM 5	75.03	7.64
TM 6 (Unmodified)	45.43	4.63
TM 6 (modified)	43.27	4.41

(2) Minor Losses

These losses are due to change in direction due to bends, elbows and enlargement & contraction of the cross section of duct.

For Bends

$$Pr. Loss = K (\rho v^2 / 2)$$

Where

K is dynamic loss coefficient

For rectangular horizontal bend value of K depends upon ratio of b/a and R/a for rectangular vertical bend value of K depends upon ratio a/b and R/b .

Value of K for horizontal bend=0.72

Value of K for vertical bend=0.405

Both the above values are for 90 degree bend.

For any other bend angle θ the value of K will be $\theta/90$ times of above value.

For Enlargements and Contractions

$$P Loss = K (\rho v^2 / 2)$$

Where

K= loss coefficient which depends on geometrical changes of the duct. The coefficient can vary from 0.17 to 0.72 as the angle of expansion increases from 5 degree to 40 degree.

Total Minor loss

Duct Leading to	(N/M ²)	mm of W G
TM 4	658.10	67.08
TM 5	801.80	81.73
TM 6 (Unmodified)	630.57	64.27
TM 6 (modified)	765.15	77.99

Total Loss= Major Loss + Minor Loss

Duct Leading to	(N/M ²)	mm of W G
TM 4	759.4	77.41
TM 5	876.83	89.37
TM 6 (Unmodified)	676	68.9
TM 6 (modified)	808.42	82.4

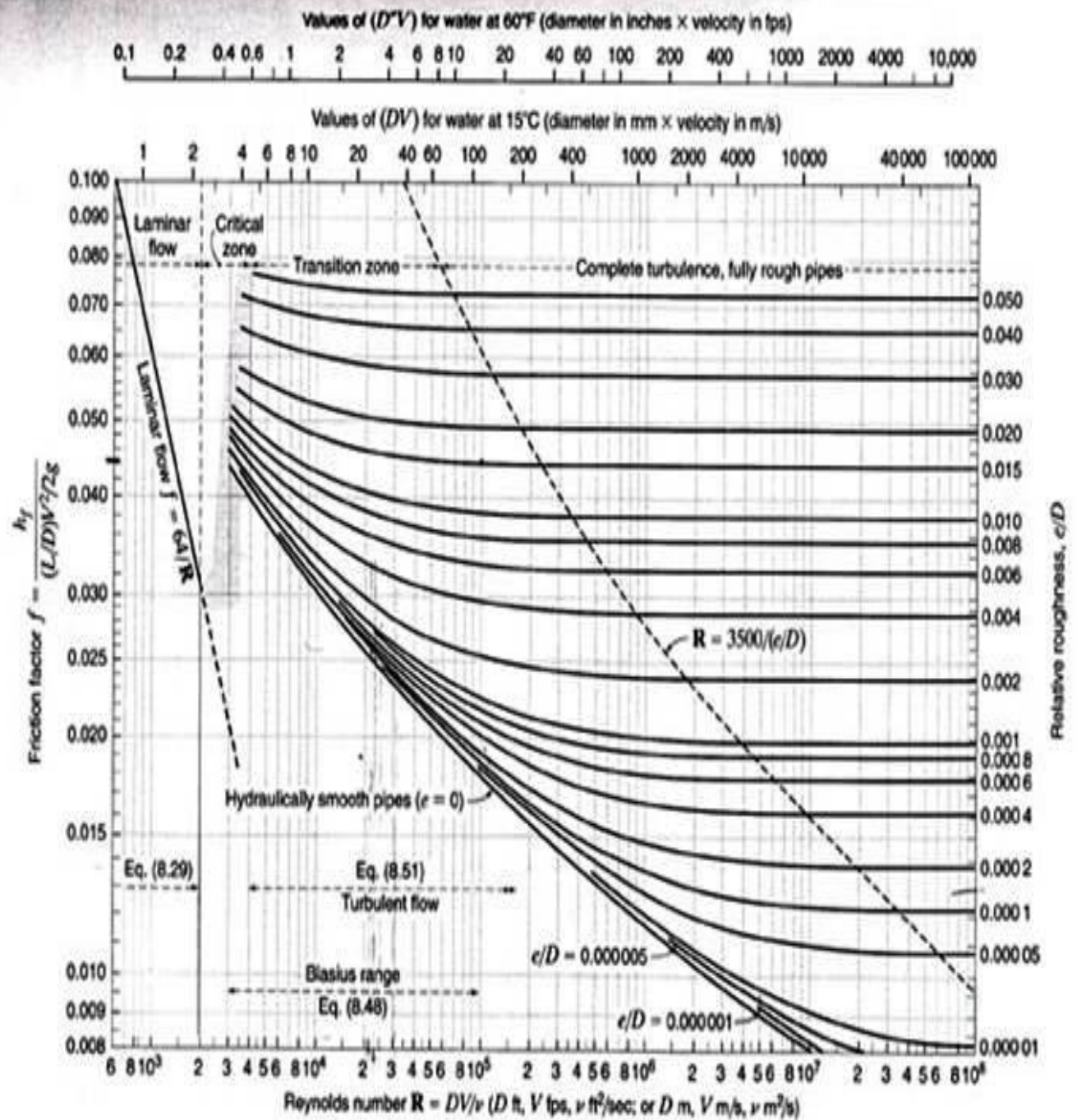
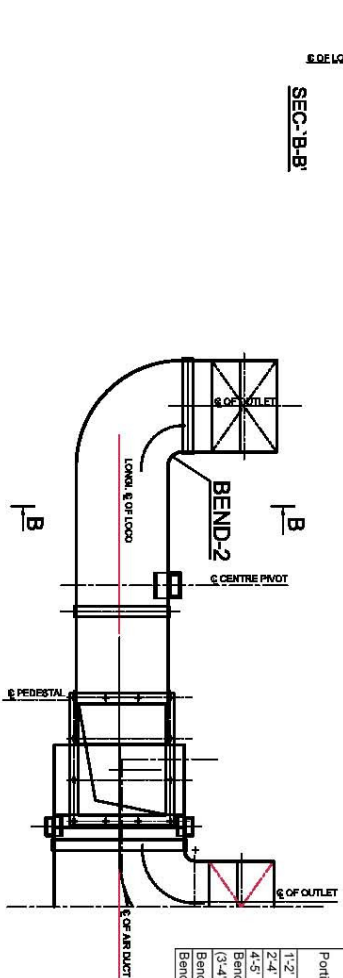
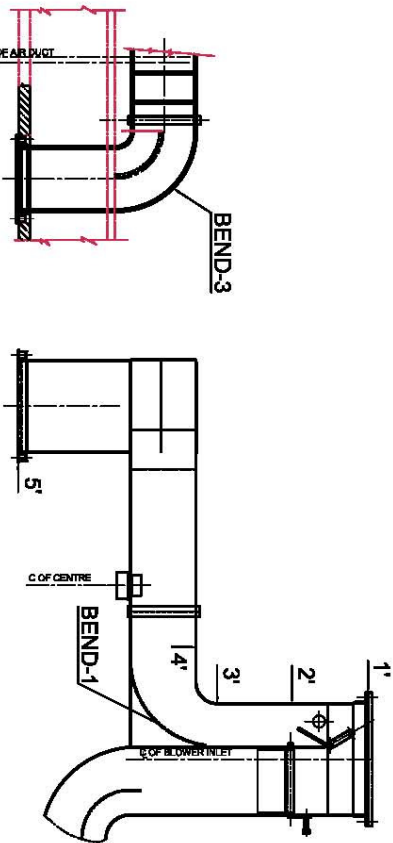


Figure 8.11
Moody chart for pipe friction factor (Stanton diagram).

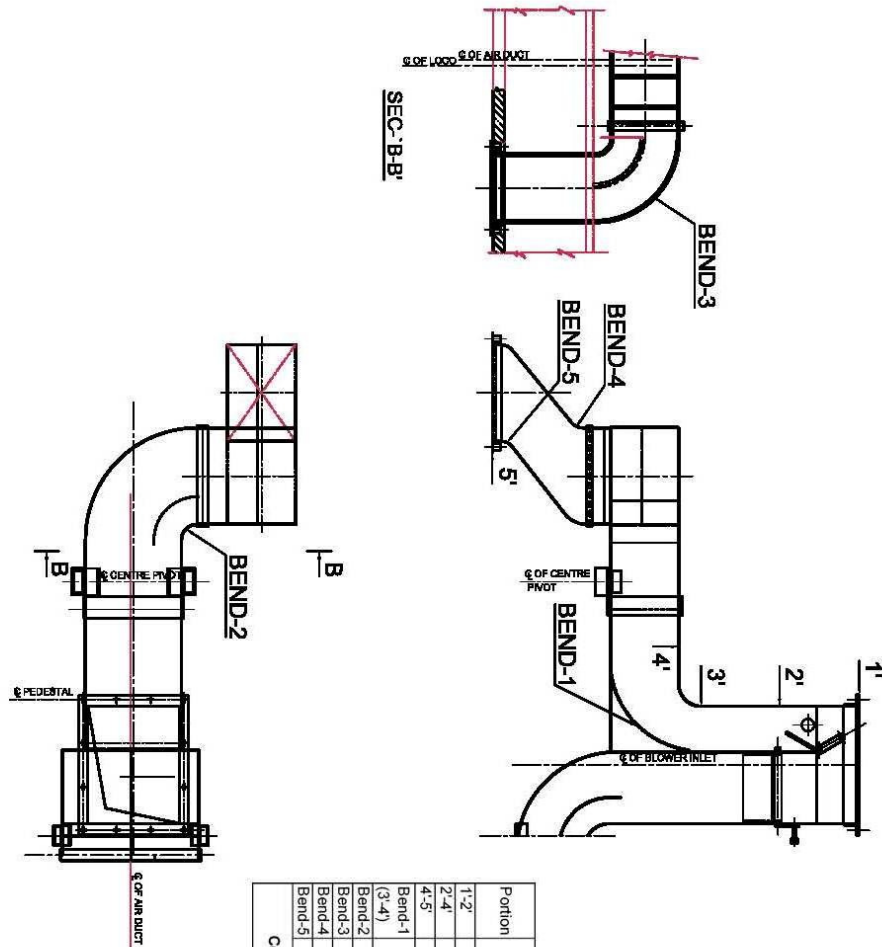
OLD DUCT



Portion	Length	Bend Angle (degree)	Coefficient	Condition	Angle (degree)	Coefficient of Fr. Loss due to enlargement/contraction
1'-2'	398	-	-	enlargement	5	0.17
2'-4'	370.5	-	-	-	-	-
4'-5'	1412	-	-	-	-	-
Bend-1 (3'-4')	200.54	90	0.3469	enlargement	24	0.51
Bend-2	-	90	0.6722	-	-	-
Bend-3	-	90	0.4060	-	-	-

FIGURE-3

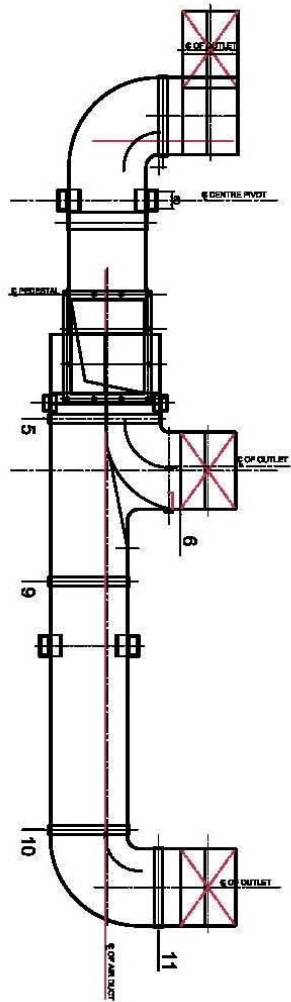
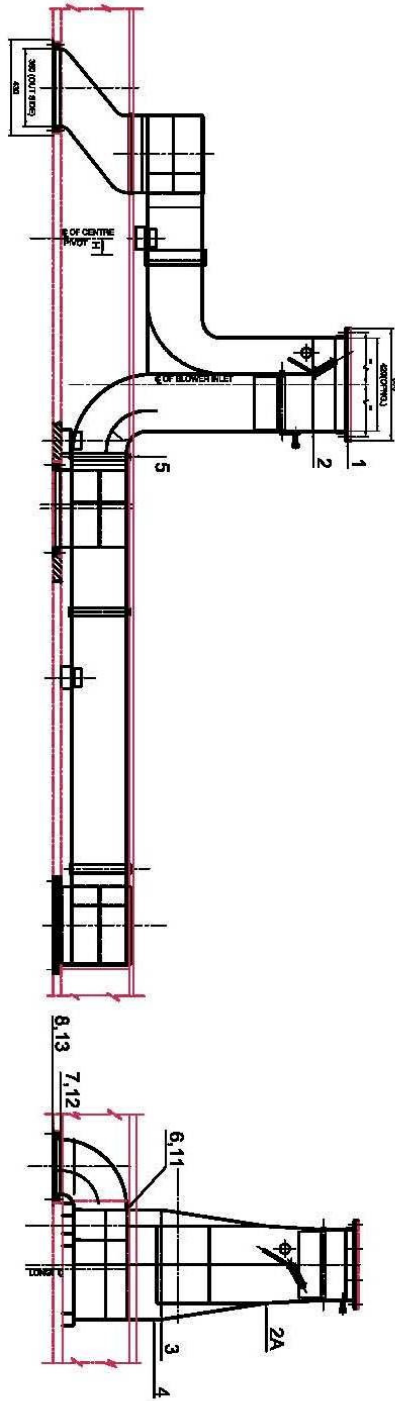
MODIFIED (NEW) DUCT ARRGT.



Portion	Length	Bend Angle (degree)	Coefficient	Condition	Angle (degree)	Coefficient of Pr. Loss due to enlargement/contraction
1-2'	388	-	-	enlargement	5	0.17
2-4'	370.5	-	-	-	-	-
4-5'	1412	-	-	-	-	-
Bend-1 (3'-4')	200.54	90	0.3469	enlargement	24	0.51
Bend-2	-	90	0.6722	-	-	-
Bend-3	-	90	0.4060	-	-	-
Bend-4	-	40	0.2988	-	-	-
Bend-5	-	50	0.3734	-	-	-

Coefficient of Pr. Loss due to bend-4 and bend-5 are taken as 8/90 times of bend-2

NEW DUCT



Portion	Length	Bend Angle (degree)	Coefficient of Fr. Loss due to bend	Condition	Angle (degree)	Coefficient of Fr. Loss due to enlargement contraction
1-2	150	-	-	enlargement	5	0.17
2-2A	248	-	-	enlargement	10	0.28
2A-3	472	-	-	-	-	-
3-4	320	-	-	-	-	-
4-5	357	90	0.315	-	-	-
5-6	314	90	0.615	enlargement	20	0.45
6-7	142	90	0.4050	-	-	-
7-8	32	-	-	-	-	-
8-9	3735	-	-	enlargement	10	0.28
9-10	1120	-	-	-	-	-
10-11	178.6	90	0.6722	-	-	-
11-12	142	90	0.4050	-	-	-
12-13	32	-	-	-	-	-