Mechanics updates of MOST2 vertex detector prototype

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Vertex detector (VTX) model

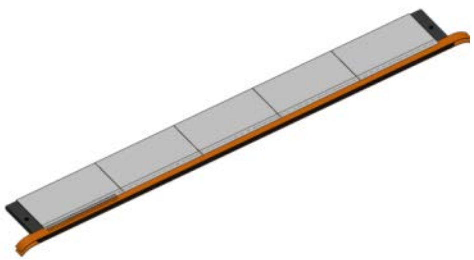
MOST2 project Goal: build a vertex detector prototype for CEPC

Sensor chip : 14.8 x 25.6 x 0.05 mm (2 mm wide margin at one side for wire bonding)

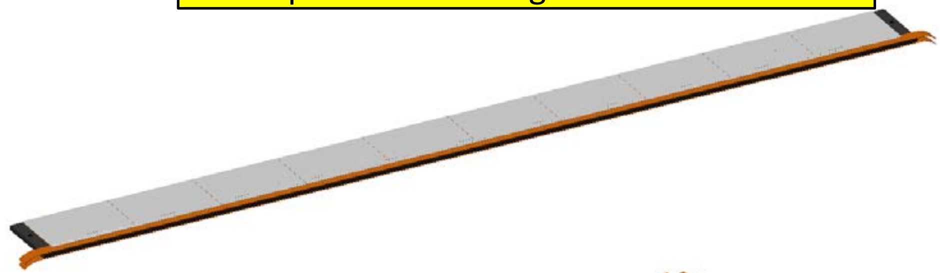
Ladder: support + chips + FPC

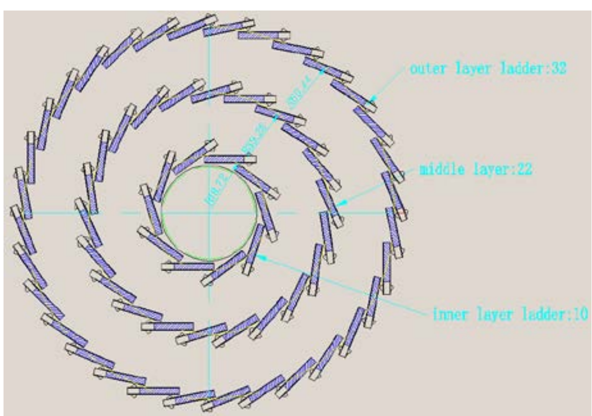
0.1mm gap between chips

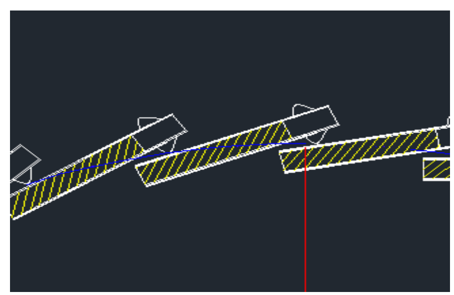
Ladder of inner layer(16.8 x 131 mm): 10 chips total including both sides

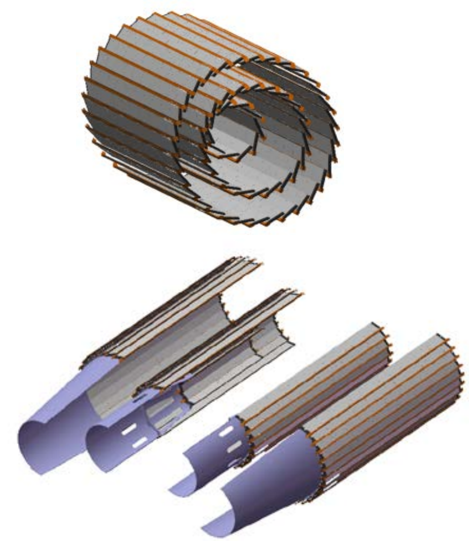


Ladder of outer two layers(16.8 x 264 mm): 20 chips total including both sides







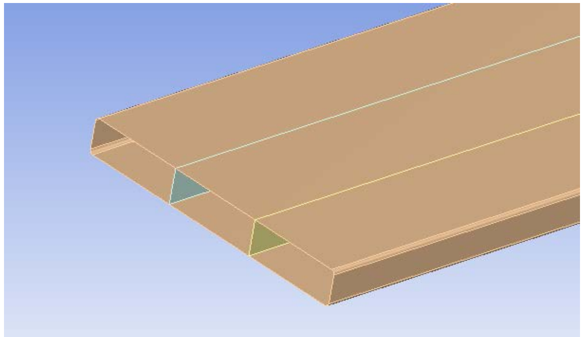


Comparative FEA analysis-1

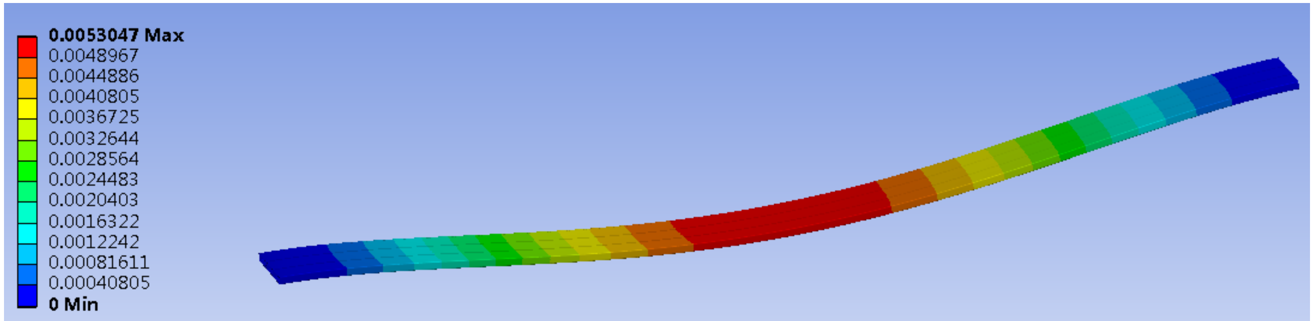
To evaluate the contribution of the sensors and FPC to the rigidity of the ladder support, two comparative FEA analysis were done based on the current preferred design.

Analysis -1 A bare ladder support with pressure load

- 2.055 g (4.11 g in total) weight of sensors and FPC on either sides of the support and evenly distributed the weight to the surfaces as pressure load.
- Self weight 2.56 g.



Max def. under full load: 5.3 um



Model of the complete ladder

A complete ladder model with:

- A Ladder support (CFRP)
- FPCs on both sides (kapton + equivalent mass of Aluminum and adhesive)
- Sensors on both sides (silicon)

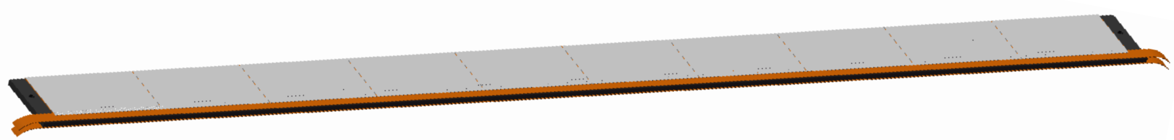
FPC laminates

Mingyi provide

	thickness
Polyimide	25um
Adhesive	28um
Plating copper	17.8um
kapton	50um
Plating copper	17.8um
Adhesive	28um
Polyimide	25um

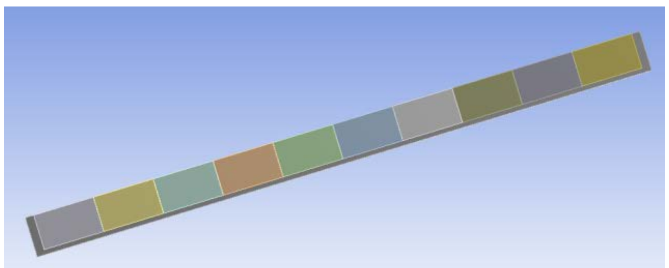
Polyimide 50+25*2 =100 um

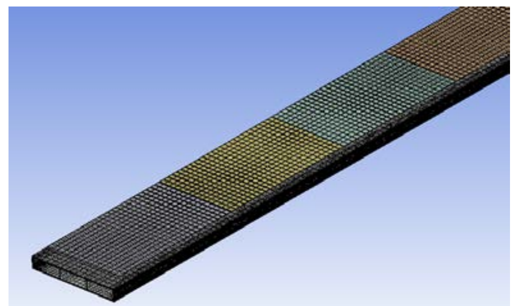
Al 18x2 =36 um

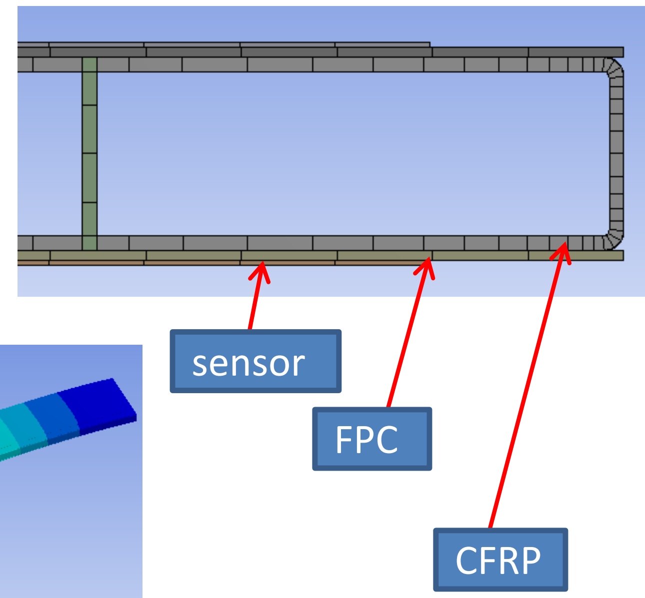


Comparative FEA analysis-2

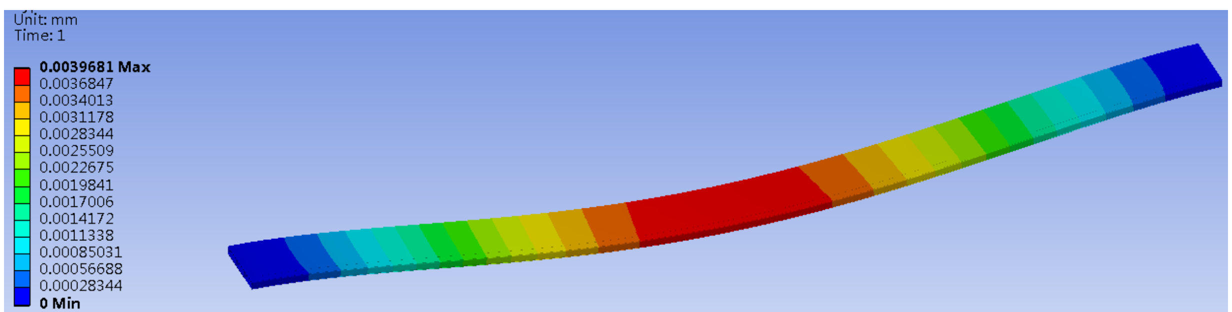
The complete ladder model including the support with sensors and FPCs on both sides has been analyzed.
The adhesive layers between the parts and the interlayers of Aluminum trace of the FPC were not considered, but the mass of these materials was added to the FPC by increasing the density of it. Total weight equal to total loads of analysis-1.





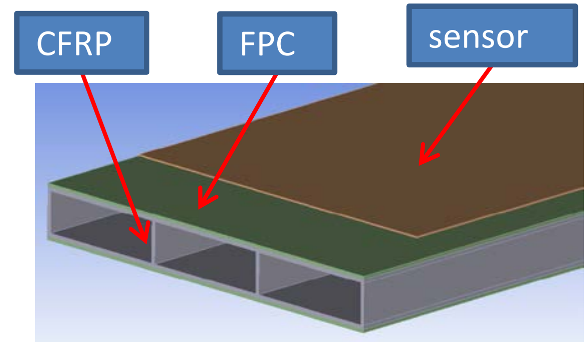


Max def: 4 um



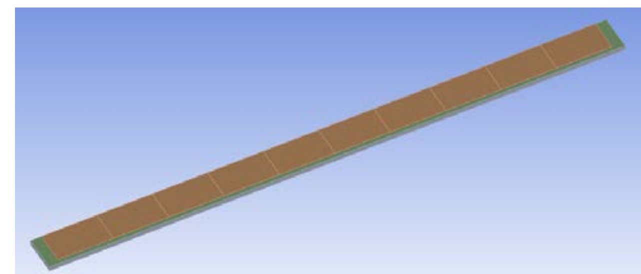
After the FPC with sensors glued on, the rigidity of the full ladder is increased by 24% compare to that of the support itself.

Cooling simulation of a complete ladder



A complete ladder model with:

- A Ladder support   (CFRP * conductivity)
- FPCs on both sides (kapton + Aluminum)
- Sensors on both sides (50 um silicon)
- adhesive not considered
- heat resistance in contact not considered



FPC laminates

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Polyimide 50+25*2 =100 um

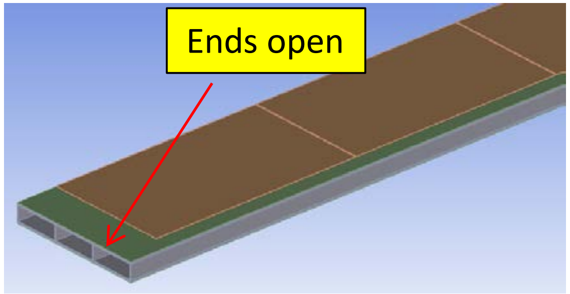
Al 18x2 =36 um

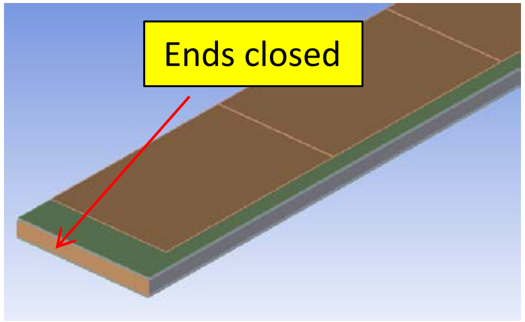
Adhesive is not considered

Cooling simulation results of a complete ladder ends open VS sealed

Power dissipation (mW/cm2)	Inlet air temperature (℃)	Inlet air velocity (m/s)	Max temperature (℃) - Ends OPEN	Max temperature (℃) - Ends SEALED
200	20	3	57.1	57.4
200	20	4	50.5	51.3
200	20	5	46.4	47.6

At a speed of 3 m/s, the difference between the ladder with open and closed ends is only 0.3 ℃ (57.4-57.1).





Compressed air cooling-continued

ladder-spt's ends open vs sealed

Simulations of a ladder with two ends of the ladder-spt sealed also had been done to evaluate the contribution of the channels to cooling effect.

Power dissipation （mW/cm² ）	Inlet air velocity （m/s ）	Material of ladder-spt	max temp. （℃） ends open	*max temp. （℃）* ***ends sealed***	max temp. （℃） Plate ends open	max temp. （℃） ***Plate*** ***ends sealed***
200	5	Al-6061	49.02(50.4)	*49.19 (*0.17)*	48.98	*49.34 (*0.36)*

Given 200 mW/cm2 power dissipation, the results show that there is not much temperature difference (less than 0.5 ℃) between sealing and opening of the ends of the ladder support.

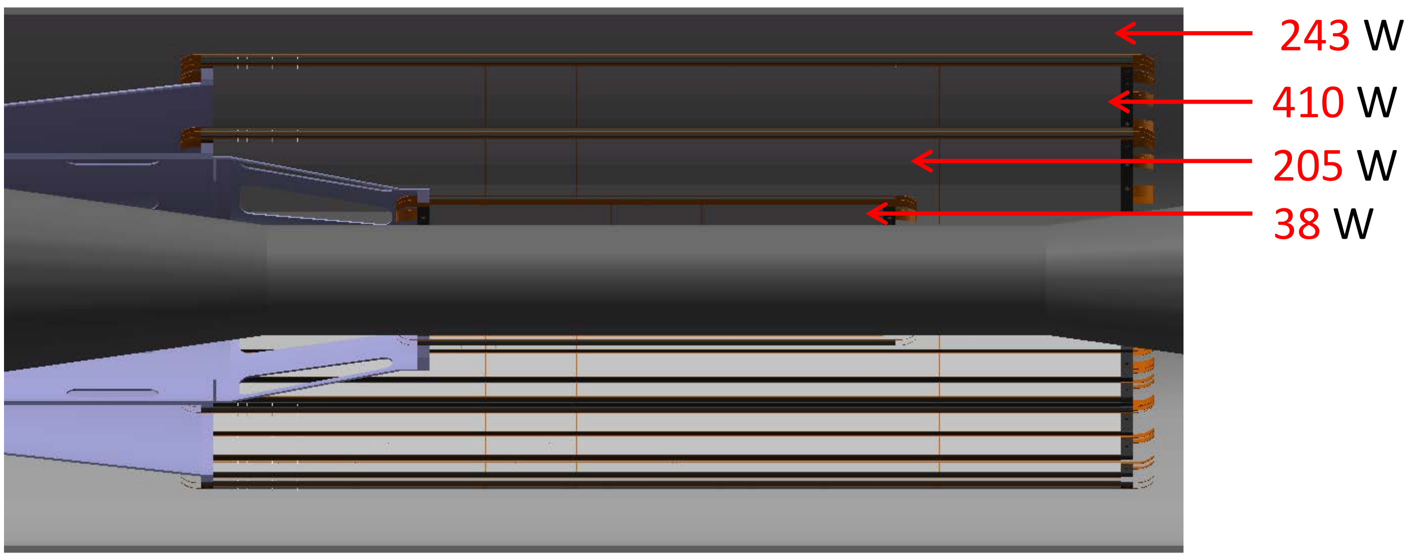
The updated results of difference in cooling effect of the different end forms of the complete ladder is consistent with the previous results (as above picture shows) of the ladder support with heat source.

Heat generation of VXT

Sensor Power dissipation:

Current (short term) goal: ≤ 200 mW/cm^2. (air cooling)

Final goal of CEPC: ≤ 50 mW/cm^2. (air cooling)

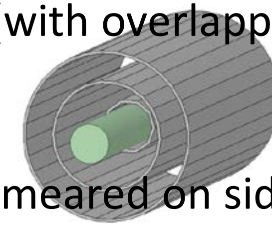


At 200 mW/cm^2 dissipation, the total heat generation is about 900 W, for CEPC level it is about 225 W.

Cooling simulation of the simplified VTX

As a first step of the overall cooling simulation, this is a rough simulation to get preliminary estimate of the feasibility of the forced air cooling. Compared with reality, below items are simplified :

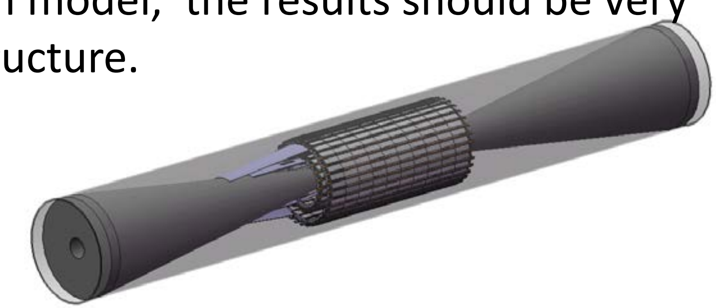
- 3 adiabatic barrels* instead of the real support structure (with overlapped ladders)



- the total heat generation of each detector layer is evenly smeared on sides of the barrel.

i.g. just sensors and forced cooling air in the cooling box (a hollow cylinder with a ID of 150mm).

Due to the properties of this simulation model, the results should be very conservative compared with the actual structure.



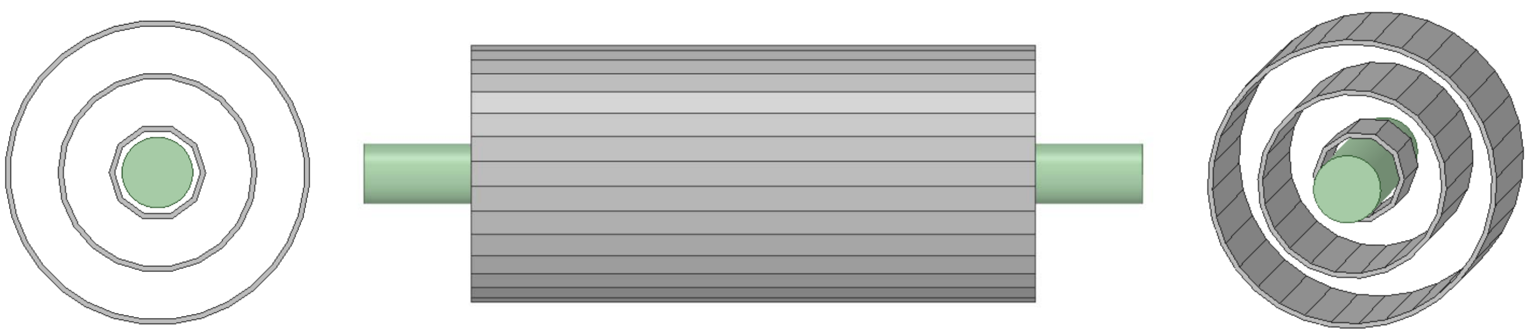
Model of the simplified VTX

Also given:

- 0 degree Celsius inlet air temperature.
- 30 degree Celsius constant temperature of beam pipe’s outer surface.

Velocity of the inlet air is variable according to different setup.

The minimum gap between the inner barrel and beam pipe is:
(D32.4-Φ30.7)/2=0.85 mm in radius direction.



Result summary

Power dissipation (mW/cm2) `	Temperature of beam pipe's surface (℃)	Inlet air temperature (℃)	Inlet air velocity (m/s)	Max temperature of inner barrel (℃)	Max temperature of middle barrel (℃)	Max temperature of outer barrel (℃)
200	*30*	*0*	*5*	113.1	76.1	73.2
200	*30*	*0*	*6*	106.7	69	66.4
100	*30*	*0*	*3*	79.2	48.5	45.7
100	*30*	*0*	*4*	74.9	42.4	39.8
100	*30*	*0*	*5*	71.2	38	36.6
50	*30*	*0*	*2*	57.1	29.1	26.9
50	*30*	*0*	*3*	54.5	24.3	22.9
50	*30*	*0*	*4*	52.3	21.3	19.9

Note that, the current simplified simulation is **very conservative** compare with reality.

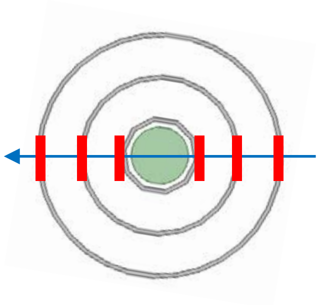
A further comparison

Power dissipation (mW/cm2) `	Temperature of beam pipe's surface (℃)	Inlet air temperature (℃)	Inlet air velocity (m/s)	Max temperature of inner barrel (℃)	Max temperature of middle barrel (℃)	Max temperature of outer barrel (℃)
50	30	0	3	54.5	24.3	22.9
The minimum gap between the inner barrel and beam pipe change to (D32.4-Φ28)/2=**2.2** mm in radius direction.						
50	30	0	3	52.9	24.2	22.8

The temperatures of the innermost barrel are different due to the change of the gap, and the trend of the effect is consistent with the previous analysis of the single ladder.

Cooling of the VTX prototype of MOST2 for beam testing

Based on considerations of the sensors cost and the air cooling feasibility, for MOST2, it is most likely that only 6 instrumented ladders on three barrels (two on each barrel), and they are deployed in a straight line for beam testing.



For the simplified VTX simulation:

- air velocity 5m/s
- Inlet air temperature: 0 ℃.
- Dummy beam pipe: 30 ℃

Due to the model property (very conservative) even only 6 ladder instrumented with heat source, the max temperature is almost the same as all ladders activated and can be up to 112 ℃.

In this case, the cooling results of a complete ladder are more valuable for reference before detailed simulation results come out in next step.

Power dissipation (mW/cm2)	Inlet air temperature (Celsius degree)	Inlet air velocity (m/s)	Max temperature (Celsius degree) - Ends OPEN	Max temperature (Celsius degree) - Ends SEALED
200	20	3	57.1	57.4
200	20	4	50.5	51.3
200	20	5	46.4	47.6

Next

Instead of 3 single barrels, a cooling simulation of the VTX with simplified **individual ladders** deployed exactly the same as the current general structure design will be studied. Besides , it will be a simulation in system level by integrating the support and fixing structures, endcap detector (if used) , cooling box, fan and griller (or inlets and outlets for CEPC), and very close to real structure and working condition.