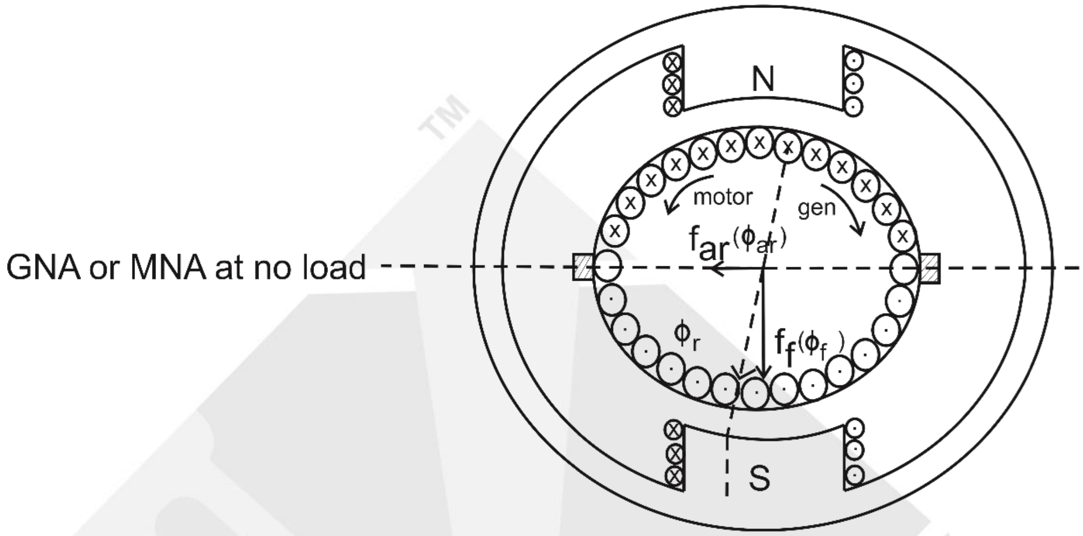
Armature Reaction

- Due to relative motion between armature conductors and field mmf there is an emf induced in armature conductors. This emf causes flow of current in armature conductors which cause armature flux. This flux is produced as a reaction to field flux and hence is called as Armature Reaction.



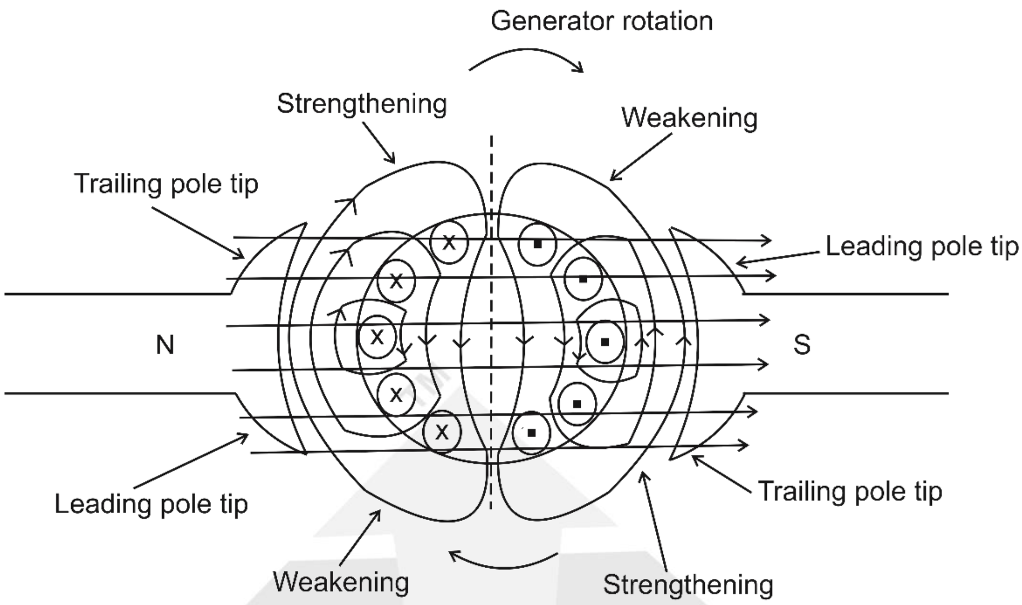
- Geometric Neutral Axis (GNA) is defined as the axis that is perpendicular to the field axis of the stator. Magnetic Neutral Axis (MNA) is defined as the axis perpendicular to the net flux that is flux due to field as well as armature mmf. The perpendicularity is taken in terms of electrical angle and not mechanical angle.

- It is well known that the brushes are placed on the MNA to collect maximum emf and also to ensure that the undergoing commutation have zero rotational voltage to prevent serious commutation problems.

- On no-load, the MNA coincides with the GNA because on No-Load there is no armature current and armature reaction can be neglected so net flux is same as field flux.

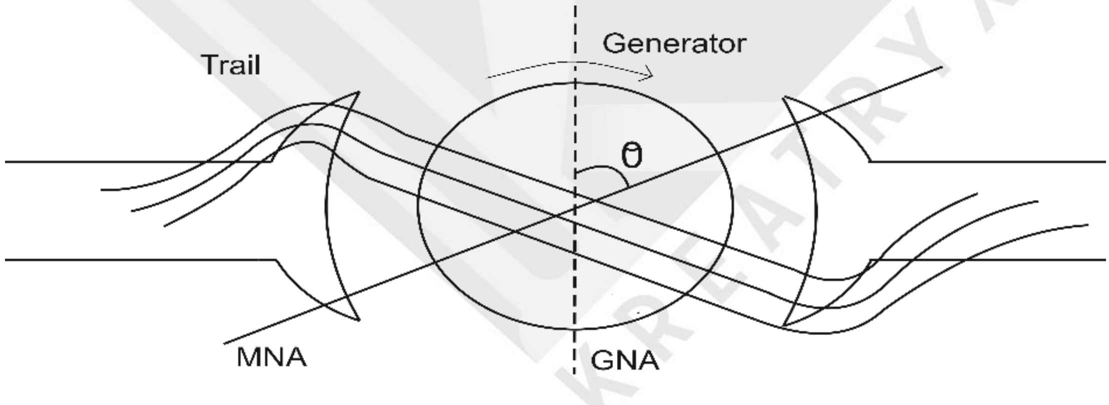
- However, when the machine is loaded then the armature MMF that is triangular in wave shape and along the brush axis causes a cross magnetizing effect on the main field resulting in to concentration of flux on the trailing pole tips in generator action and leading pole tips in motor action.

- Leading Pole Tip is the tip of the pole encountered first by the armature in the direction of rotation and trailing pole tip is the tip which is encountered after the leading pole tip.



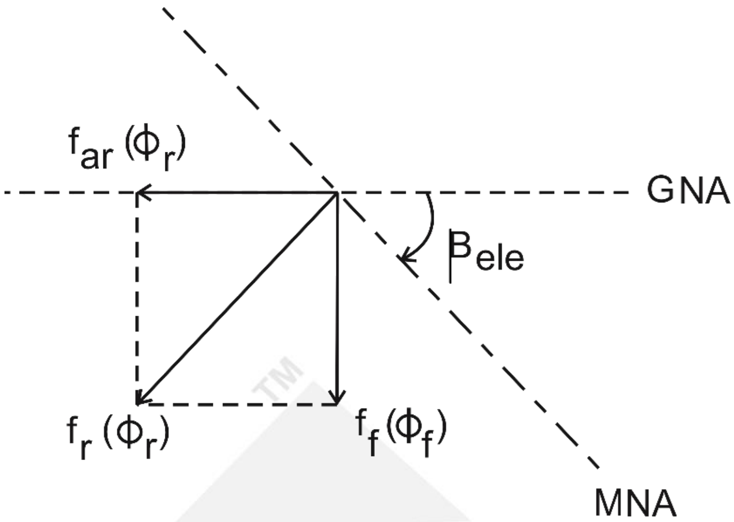
- Flux is strengthened where armature and field flux lie along the same direction and weakened where armature and field flux lie in opposite directions.

- So, magnetic field is strengthened at trailing pole tips and weakened at leading pole tips.



- If strengthening effect = weakening effect, the average flux under the pole remains same and therefore no demagnetizing effect of Armature Reaction. But due to saturation, strengthening effect < weakening effect so average flux under each pole reduces and hence Armature Reaction is demagnetizing.

- The Phasor Diagram for Armature Reaction is shown below:



- Consequently, the MNA is no longer on the GNA but shifts in the direction of rotation for generator action and in a direction opposite to rotation for motor action.

- Since, Armature Flux is perpendicular to Field Flux so the nature of Armature Reaction is cross magnetizing.

Effect of Cross Magnetizing Armature Reaction

- MNA shifts in direction of rotation in case of generator and opposite to direction of rotation in case of motor. The amount of shift $\propto I_a$

- The iron losses are increased because B_{max} is increased.

- Due to presence of air gap flux along the brush axis, an emf is induced in coil which is undergoing commutation, so commutation process is delayed, so sparking at brushes occurs

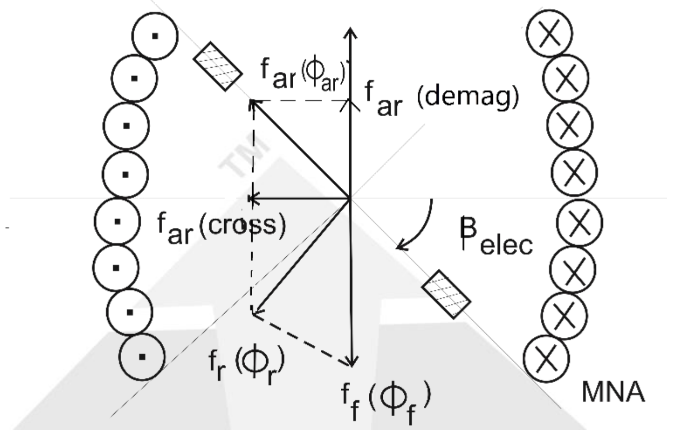
- The ϕ is maximum under trailing pole edge, so induced emf is maximum for conductors lying under this pole edge and if this induced emf increases beyond 30-40V, the mica insulation fails, hence sparking takes place between adjacent commutator segments.

Methods of Reducing Armature Reaction

- If the brushes are left on GNA, then emf collected would reduce and coil undergoing commutation would no longer have zero rotational voltage leading to serious commutation problems. The immediate solution therefore, appears to shift the brushes in the new MNA.

- The brush shift results into improved commutation but reduces thus resultant flux resulting into reduction in emf in generator action and increase in speed in motor action.

- $F_{ar}\text{ (demagnetizing)} = \frac{Z/2}{P} \times \frac{2\beta_{erec}}{180^\circ} \times \frac{I_a}{A}$



- Brush shift has serious limitations. Since, shift in MNA is proportional to Armature Current the brush has to be shifted in a new position every time the load changes, direction of rotation changes or mode of operation changes.

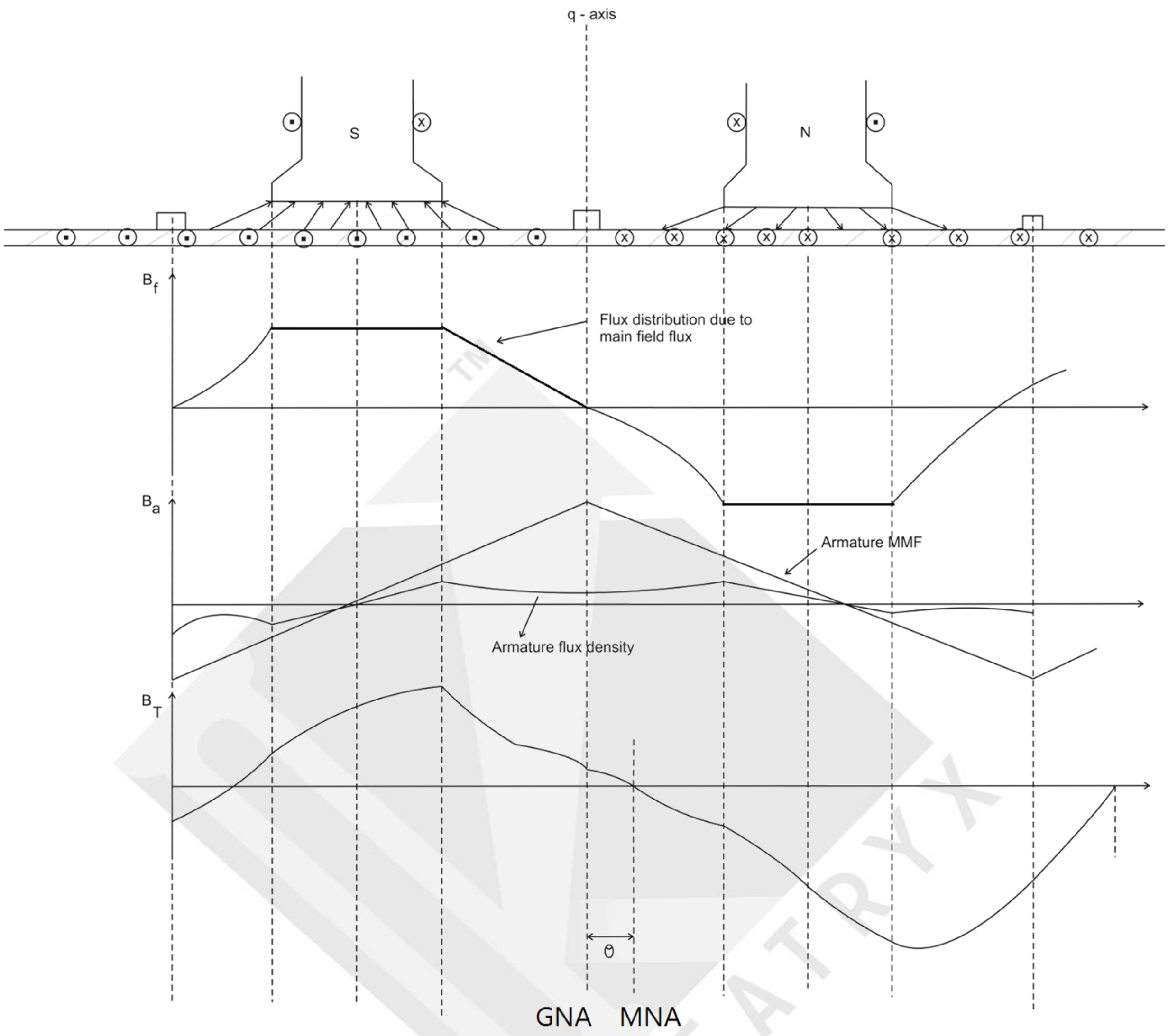
- Therefore, brush shift is limited to various small machines and there too the brushes are fixed at a position corresponding to expected load, direction of rotation and mode of operation.

- In practice the brushes are moved slightly further to counter the effect of reactance voltage that would further improve commutation.

- Brushes are shifted in direction of rotation for a generator and opposite to direction of rotation for a motor.

- In larger machines, inter poles also called commutating poles are used to overcome commutation problems.

- Armature reaction waveforms are shown below:



- Armature MMF from the above figure is triangular in shape and due to large air gap along q-axis the armature flux density is reduced along q-axis.

- The point where total flux density is zero is defined as Magnetic Neutral Axis and where flux density due to poles is zero is defined as Geometric Neutral Axis. From above figure due to Armature Reaction there is a shift between the two.

<u>Solved Examples</u>

Problem: A 4 pole generator supplies a current of 143A. It has 492 conductors lap connected and delivering full load, brushes are given a shift of lead to 10° .calculate demagnetizing ampere turns per pole? The field winding is shunt connected and takes 10A. Find no. of extra shunt turns necessary to neutralize this demagnetization.

Solution: $I_a = 143 + 10 = 153A$

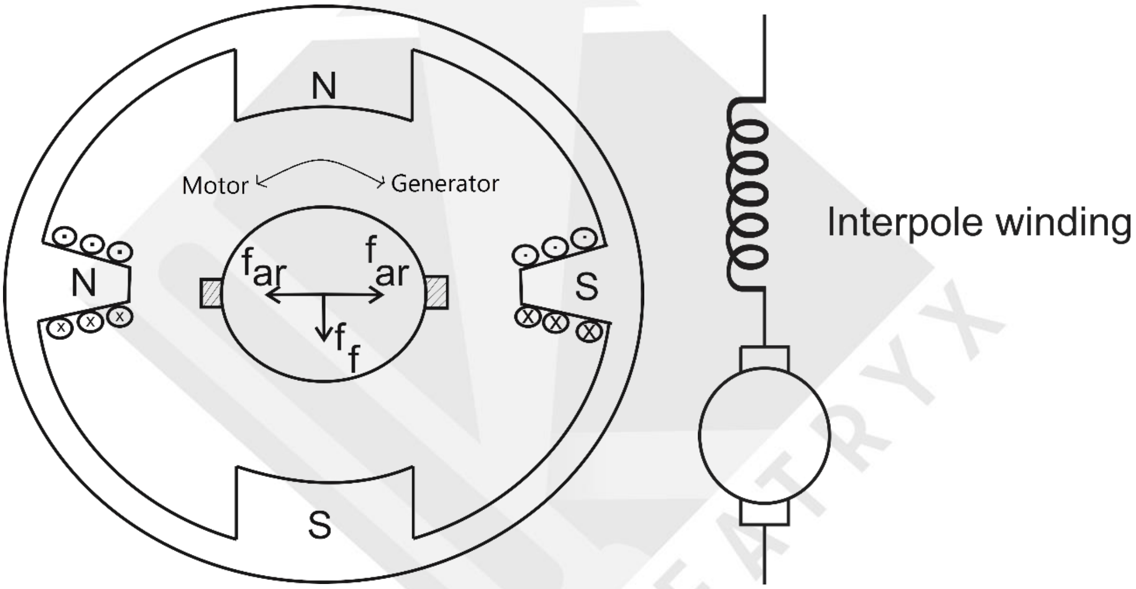
$\beta = \frac{P}{2} \times 10^\circ = 20^\circ$

far (demag)= $\frac{492}{2 \times 9} \times \frac{2 \times 20^\circ}{180^\circ} \times \frac{153}{4} = 522.75$ AT/pole

Extra field turns= $\frac{522.75}{10} = 53$ turns

Interpoles

- Interpoles are long but narrow poles placed in inter polar region and has the polarity of succeeding (incoming) poles for generator action and preceding poles for motor action.



- The inter pole winding is designed to neutralize armature MMF in interpolar region. It has an additional duty to create an interpolar flux density that induces a commutation voltage in the coil undergoing commutation such that it cancels reactance voltage of the coil.

- The interpole winding carries the armature current as it is connected in series with the armature winding. The presence of inter poles ensures sparkless linear commutation

- The inter pole is kept narrow so that influence is restricted to coil undergoing commutation only and does not spread to other neighboring coils. However bar is wider at bottom to prevent saturation and improve response.

- Inter poles work satisfactorily irrespective of the load, the direction of rotation and mode of operation of the machine.

Compensating Winding

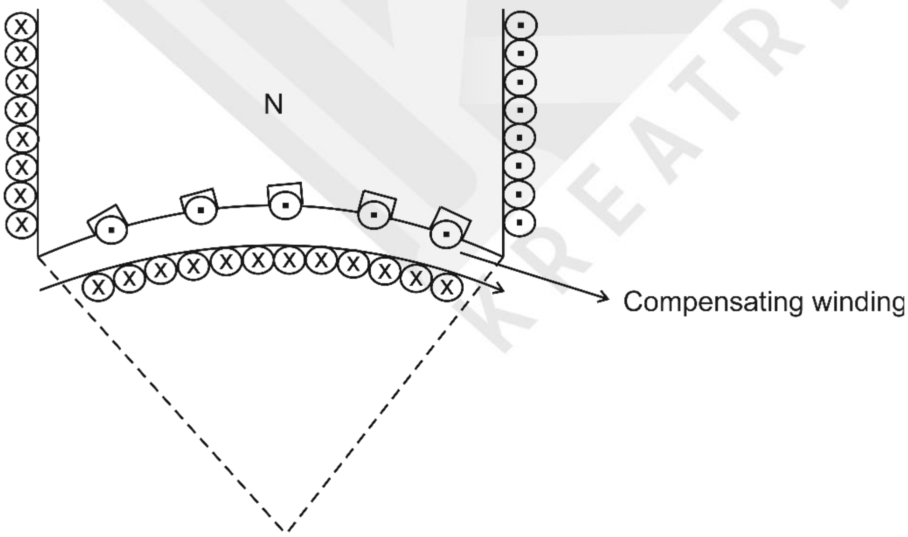
- The cross magnetizing armature reaction effect that causes concentration of flux under one pole tip is caused mainly by the conductors that lie under the pole are

- When the machines are heavily loaded, the flux density at these tips becomes very high resulting in higher than normal induced voltage between concerned adjacent commutator segments.

- This may cause a spark over between adjacent commutator segments more so because these coils are physically close to the commutation zone where air temperature is high and favorable for spark over. This may lead to other segments also getting involved and resulting in fire over entire commutator segment.
- Also if load is rapidly fluctuating (e.g. rolling machine), $L\frac{di}{dt}$ voltage of coils may become high enough to start a spark over between adjacent commutator segments. This phenomenon will start from the coil under the pole center and it would have maximum.

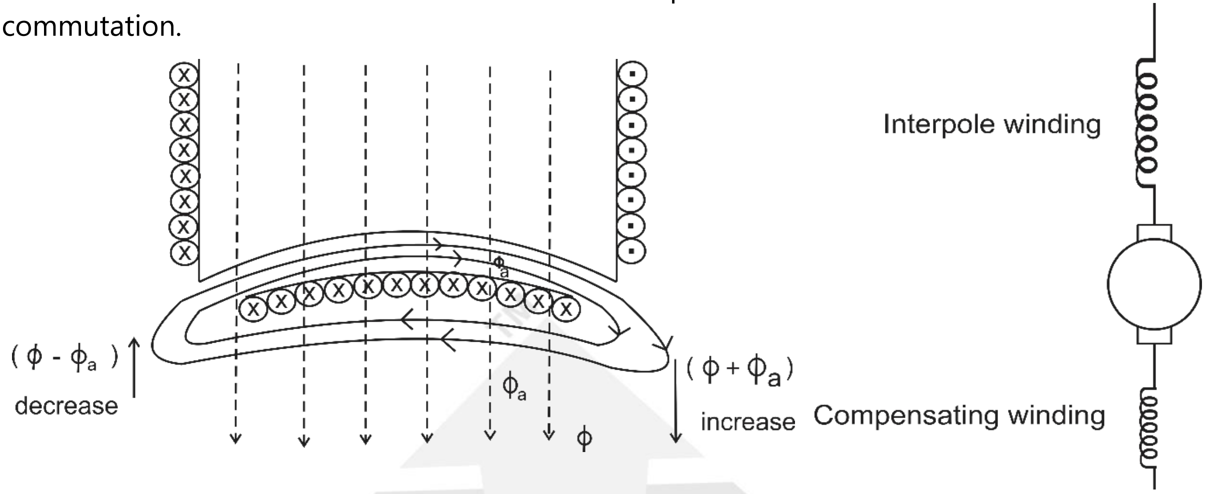
- This problem is more acute when load is decreasing in generator and increasing in motor.

- The above problems may be overcome by use of compensating winding. Compensating winding consists of conductors embedded in pole faces and carry armature current in a direction opposite to armature conductor current under pole arc.



- The compensating winding may be designed to completely neutralize the armature MMF of the conductors that lie under the pole are resulting into restoration of main field flux.

- The presence of compensating winding reduces the duty of inter pole winding to the extent of armature MMF of conductors under the pole are and therefore can be set to aid commutation.



- For compensated machine
  - $f_{comp} = \frac{Z/2}{p} \times \frac{\text{pole arc}}{\text{pole pitch}} \times \frac{I_a}{A}$ AT/pole
  - $N_{comp} = \frac{Z/2}{p} \times \frac{\text{pole arc}}{\text{pole pitch}} \times \frac{1}{A}$ turns
  - $F_{interpolar} = \frac{Z/2}{p}\left(1 - \frac{\text{pole arc}}{\text{pole pitch}}\right) \times \frac{I_a}{A} + \frac{B_{int}}{\mu_o} \times L_{interpolar\,gap}$ AT/pole

- Compensating winding reduces armature circuit inductance and therefore improves time response. Because it neutralizes AR under pole faces only.

- It increases cost of the machine but works satisfactorily under all conditions