FANS

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1. INTRODUCTION

‘ Fan ’ is one of the many types of turbo machines used for energy transfer. It can be defined as a rotating machine with a bladed impeller which maintains a continuous flow of air or gas. It is continuous because the flow at entry and exit and also through the impeller is steady. This differs from the flow in a positive displacement machine where the flow is pulsating.

2. PRINCIPLE OF WORKING

It is possible that energy transfer can be from the machine to the flowing fluid or vice versa.

Fans, blowers, compressors, pumps etc., fall under one category where energy transfer occurs from the machine to the fluid, i.e. Mechanical Energy is converted to Fluid Energy. The principal distinction between Fans, Blowers, Compressors and Pumps is that the Pump handles liquid, whereas the others handle air or gas.

Turbines fall under another category, where energy transfer is from the fluid to the machine. In other words the first category (e.g. Fans) consume power as they rotate with the help of prime mover and energizes the flowing fluid whereas turbines rotate due to the fluid energy imparted to it and helps in generating power.

3. CLASSIFICATION OF FANS

Fans may be classified into two major types - Axial flow and Radial Flow

3.1 Axial Flow Fans

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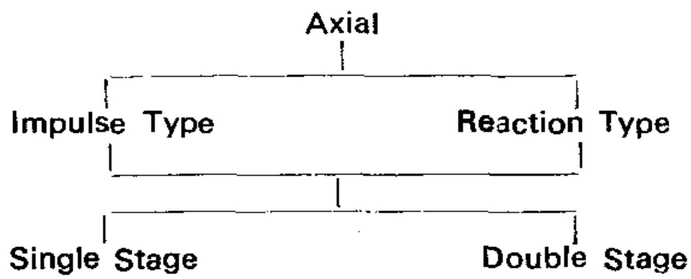
3.1 Axial Flow Fans



In axial flow fans the main flow is parallel to the axis of rotation of the fan both at entry and exit.Axial fans may be classified further into Impulse Type and Reaction Type fans.

In the Impulse type fans, most of the energy coming out of the impeller is Kinetic Energy. It is converted into Pressure Energy in the Outlet Blades and the diffuser. Hence these fans are called Impulse Fans.

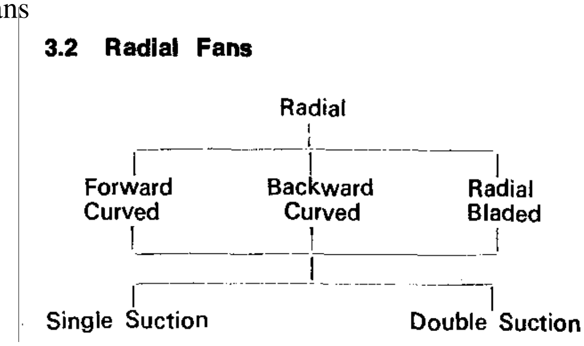
In the reaction type of Axial Fans, most of the energy coming out of the impeller is in the form of Pressure Energy. It is known that Degree of Reaction.

$$R = \frac{\text{Stailc Pressure Rise Across the impeller}}{\text{Total Pressure Rise}}$$

The value of R for impulse fans is less than 0.2 whereas for reaction fans R is around 0.8.

The pressure rise for an individual fan can be increased multifold by arranging two or more impellers in series in the same housing depending upon the requirement. This is called staging. In fans so far two stages have been given by . Suppose the total pressure rise required is ' P ', then individual impeller is designed to develope P/2, whereas the flow rate remains the same for both the impellers.

3.2 Radial Fans



Based on the configuration of the blade with respect to the direction of rotation of the impeller (as shown in the Fig. -1 it is called Backward Curved, Forward Curved and Radial Bladed impeller.For better understanding it can be mentioned that the blade angle at exit X is less than 90^0 equal to 90^0 and greater than 90^0 in B.C. Bladed, Radial Bladed and F.C. Bladed Impellers respectively.
Ideal characteristic curves for the different types of radial impellers have been shown in the Fig. -2.If one superimposes the various losses in the respective lines then the actual characteratic curves will be got. They Will be parabolic in shape.

Backward curved impellers are the best efficient among the three and hence mostly used. Forward Curved impellers have the overloading characteristic and are more power consuming. Because of the self cleaning characteristics of the Forward Curved Bladed impeller they are used in some ID applications of recovery boilers.

4. FAN DESIGNATION

is presently in collaboration with M/s. KKK, West Germany for the manufacture of fans. Under this both Radial and Axial Fans are manufactured. The designations used for different fans are as follows:

4.1 Radial Fan

4.1.1 NDFV Y Z — Ref. (Fig. XIII-3)

- **Z** — Type of Wheel b, c, d, etc.,
- **Y** — Nominal tip diameter of impeller in decimeter.
- **NDFV** — Radial single suction overhung impeller with inlet guide vane control.

4.1.2 NDV Y Z — Ref. (Fig. XIII-4)

- **Z** — Type of wheel
- **Y** — Nominal tip dia of impeller in decimeter
- **NDV** — Radial single suction — Simply supported impeller

4.1.3 NDZV Y Z — Ref. (Fig. XIII-5)

Tvpe of wheel

- **Z** — Type of wheel
- **Y** — Nominal tip dia of impeller in decimeter
- **NDZV** — Radial double suction — Simply supported impeller

4.2 AXIAL FAN

A N m e6 — Ref. Fig. XIII-6 & VIII-7

- **e6** — Diffuser designation
- **m** — Nominal tip diameter of the impeller in decimeter
- **N** — Non-profiled bladed (constant thickness)
- **A** — Axial.

4.2.2 A P X Y Z — Ref. (Fig. XIII-8)

- **Z** — Hub diameter in decimeter
- **Y** — Tip diameter in decimeter
- **X** — Number of stages
- **P** — Profiled bladed
- **A** — Axial.

5.1.0 CONSTRUCTIONAL FEATURES (NDFV FANS) Fig. 3

5. CONSTRUCTIONAL FEATURES

(NDFV FANS) Fig -3

The major sub-assemblies may be listed as

1. Spiral Casing
2. Impeller
3. Inlet guide vane control assembly
4. Shaft with bearing assembly
5. Seal assembly

5.1.1 Spiral Casing

It consists of two parallel side walis, spiral plate, inlet cone. The casing is a fully welded structure stiffened by rolled sections both inside and outside. The spiral wall is rough rolled initially and then corrected while welding the side walls. The inlet cone which forms the entrance to the spiral casing helps in accelerating the flow. On to the inlet side flange of this cone the IGV is mounted. Manhole is provided in the spiral casing. Drain connection has been given at the lowest point of the casing. The casing rests in the foundation by means of four rigid footings. For maintenance, lifting eyes have been provided.

5.1.2 Impeller

The impeller is a welded structure consisting of back plate, cover plate, impeller ring, blades and hub.

Blades have been welded on to the back plate and cover plate with proper welding sequence. The impeller ring is welded to the inlet side of the cover plate at its inside diameter. The hub is welded to the back plate. Hub will have a taper bore for the mounting of the impeller on to'the shaft. The taper mounting is discussed in detail at a later stage. The impeller is dynamically balanced.

5.1.3 Inlet Guide Vane Control Assembly

It is a one piece housing flanged at both sides, one connected to the inlet cone flange and the other to the flange of the inlet bell. The blades of the lGV are of thin sheets fixed on to the individual shafts by rivets. All the IGV shafts are connected to a common ring through angular joints and levers. The ring is divided and it is externally actuated by a power cylinder or servoMotor.

5.1.4.0 Shaft with Bearing Assembly

5.1.4.1 Shaft

It is a solid shaft dynamically balanced. Critical speed will be well above the operating speed (more than 30%). One end is having a taper on to which the impeller is mounted and the other end is having provision for taking one coupling half through key. Torque is transmitted through the keyed joint on the coupling side and by the taper fit to the impeller. Shaft is provided with oil holes and grooves for hydraulic mounting and dismounting.

5.1.4.2 Bearings

Bearings for this NDFV fans are monoblock design with two cylindrical roller bearings and one angular contact ball bearing kept in the same housing. Bearings and housing are the same for fan siz;s 18-25. The bearings are lubricated by stand oil. Presently forced oil circulation system has also been envisaged as a safety measure in meeting the bearing high temperature problems,

The advantages of the monoblock design are that the shaft is of shorter length. Hence it is easy for machining the bearing locations in one setting and avoids a lot of misalignment. It is shop assembled due to its compactness and hence only impeller mounting is done at site.

5.1.5 Seal Assembly

The sealing of the shaft passage through the spiral is effected axially by means of labyrinth and radially by asbestos strips. The labyrinth seal is centred and fastened at the bearing housing. As a consequence it is possible to adjust the gaps in the labyrinth seals very precisely.

5.2.0 Constructional Features: (NDV & NDZV Fans) Figs. XIII-4,5
The fan as a whole can be divided into some major sub assemblies.

1. Spiral Casing
2. Impeller
3. Shaft
4. Bearings
5. Damper Assembly
6. Sealing.

NOTE: Difference between NDV & NDZV fans is that one side suction chamber with damper is absent in NDV fans.

5.2.1 Spiral Casing

The spiral casing consists of two parallel side walls, spiral wall, suction chamber and inlet cone. It is split horizontally in the shaft axis plane. If necessary upper portion will also be vertically split off contre so that impeller installing is easy. The inlet cones and the suction chamber are welded to the side walls. The casing walls, spiral wall and the suction chamber walls are reinforced by rolled suctions. Also the inside is reinforced without affecting the flow through the casing.

The inlet cone helps in accelerating the flow and supports the inlet ring.

5.2.2 Impeller

The impeller is a completely welded structure. It consists of centre plate or back plate, cover plate, blades. The blades are welded between back plate and cover plate. Proper welding sequence is followed to have minimum distortion.

The three different impellers are:

NDV - Single Suction with full back plate

NDZV - Double Suction with common full centre plate

NDZV - Double Suction saw-tooth type centre plate

The saw tooth type wheel design has the centre plate recessed between the blades. The other things are same.

Blades are all of circular single arc profile. The impeller ring comes at the inlet dia. of the cover plate.

The centre and hub discs have a machined groove which ensures central location of the wheel relative to the shaft during operation (running fit). The internal recess of centre and hub disc permits central assembly (assembly fit).

To protect the connection from wear between impeller, shaft and centre disc a conical cover plate is provided which is fixed to the centre plate for NDZV fans and fixed to the hub disc in the case of NDV fans.

Upon completion of all welding operations, the impellers are stress relieved. It is dynamically balanced.

5.2.3 Shaft

The shaft is a hollow tube with two end pins shrunk fit at the two ends and welded. Torque is transmitted through the fit and the weld is only for securing purpose. The tube is controlled at the inside diameter The shaft ends are machined after welding. A flat split ring is welded on to the shaft tube for taking up the shaft flange. The completed shaft is dynamically balanced.

The shaft's first critical speed must be at least 35% above the operating speed. It is so dimensioned to meet this requirement.

5.2.4 Bearings

The impeller is mounted on pillow block bearings. One is a locating bearing and the other is a non locating (free) bearing. The bearings are spherical roller type housed in SOFN bearing housing. Temperature gauges are provided on the housings for each bearing.

For special customer demands sleeve bearings are also provided.

5.2.5 Damper Assembly

This consists of a single piece casing, damper flaps, damper bearings and the actuating mechanism.

It is a welded casing flanged at both ends. The bearing pedestals are mounted to the side walls by screws.

There are 3 to 5 flaps fixed by screws on to their shafts which are supported by pedestals providing dry lubrication. The flat shafts carry clamping levers and the adjusting torque is transmitted by feather keys and the individual clamping levers are connected by a linkage.

In double suction fans the two damper assemblies at the two suction chambers are connected through universal joints and driven only from one side. Depending on the site conditions the drive can be arranged on the linkage side. The adjusting travel is same for all tan sizes. Connection to the drive unit is provided by an adjusting rod with ball joints. A graduated plate indicates the flap position in degrees.

5.2.6 Seals

Sealing for the shaft with the spiral casing consists of a labyrinth section for axial and an asbestos strip for radial sealing. The labyrinth seal is centrally located and screwed to the bearing pedestal which helps in precise controlling of the labyrinth passage.

The asbestos strip ensures that the movement of the spiral casing during hot conditions relative to the impeller wheel does not affect the fan function.

The unmachined flanges of the spiral casing are sealed with asbestos rope.

5.3.0 Constructional Features of 'AN' Fan (Fig. X111-6)

The fan consists of the following subassemblies along the flow path.

5.3.1 Suction Chamber

The suction chamber is of welded sheet construction and is split horizontally for easy assembly and dismantling. The suction chamber is provided with a manhole for checking the inlet of fan and removal of shaft. The suction chamber can be positioned at any inclination along its axis to suit the layout.

5.3.2 Inlet Guide Vane

The axial inlet guide vane control assembly of the fan consists of number of aerofoil vanes fixed to individual shafts, each sup ported by bearing pedestal. These guide vane shafts are connected to a regulating ring by means of angular joints. This gives a positive and precise link mechanism. The regulating ring is guided to rotating position by a set of rollers and spring assemblies called Suspension Assemblies. A control lever is connected to the regulating ring which can be operated by the external actuator. The inlet guide vane assembly is split to facilitate easy handling and dismantling. The inlet guide vane assembly i's provided with hood to avoid rusting and dust settling. This hood is provided with hand holes for lubrication.

5.3.3 Impeller Housing

Impeller housing is a welded sheet metal and of undivided construction. A peep hole is provided in the housing for checking the wear on the impeller. A conical piece is provided in the housing which is supported by a set of outlet guide blades. This conical piece support the inner bearing assembly. These outlet guide blades serve to direct flow axially and to stabilise the drift flow caused in the impeller. The outlet blades for fans handling dust laden gases are of removable type from outside of the fan. During operation of fan these blades can be replaced one by one.

5.3.4 Impeller

The impeller hub is of welded sheet metal construction in which non-profiled solid blades are welded. The impeller hub is strengthened by stiffeners and a cover plate. Impeller is dynamically balanced to the required quality level.

5.3.5 Diffuser

Diffuser of the fan is of welded sheet metal 5.4.1 construction with a core inside. The core of the diffuser houses the inner bearing and is supported by the outlet blades on one end and by struts on on the other end.Thediffuser core is provided with a manhole with access from diffuser casing so that the inner bearing can be checked even during operation of the fan. For fans handling hot gases the diffuser core is insulated inside. A cooling pipe is provided in the core to have natural cooling or forced cooling of the inner bearing. The lubricating pipe as well as the thermometer for the inner bearing are brought outside through the cooling pipe for easy access. The core is provided with a monorail and a travelling trolley to hold the shaft during the removal of the impeller.

5.3.6 Shaft and Bearings

AN' Fans are provided with hollow shaft with a flange welded on to the shaft. Impeller is fixed to the shaft flange by means of screw ring. The impeller is supported in between the bearings. The bearings are self aligning antitriction roller type. The inner bearing near the impeller side is the fixed bearing and the outer bearing near the coupling is the expansion bearing. These bearings are grease lubricated. Lubrication points are easily accessible. A grease quantity control ring is provided on each bearing to discharge the surplus amount of grease. For indication of bearing temperature a contact thermometer is provided in each bearing housing. The contact temperature should be pre-set in the thermometer to 95 Deg.C for alarm and 105 Deg.C for trip.

5.4.0 Constructional Features of ' AP' Fan (Fig. -7)

The major sub-assemblies of this type of fans are:

1. Suction Chamber
2. Shaft with Bearing Assembly
3. Impeller Assembly
4. Servomotor Assembly
5. Diffuser Assembly

5.4.1 Suction Chamber

This is a completely welded structure suitably stiffened to reduce the vibrations. Mainhole is proviced for accessibility.

5.4.2 Shaft with Bearing Assembly

The bearings for this fan are placed inside a common housing and they are shop assembled on to the shaft. It is very compact as the housing is placed inside the static hub (nose) which guides the flow to the impeller. To one end of the shaft the. impeller is either flange mounted or taper mounted depending upon the size of the fan. This main shaft is connected to the prime mover by means of an intermediate shaft with flexible coupling.

5.4.3 Impeller Assembly

This is the most sophisticated and complicated part of the fan. It is a highly precision machined and close toleranced one. The hub surface is spherical and 23 blades are located on the periphery. The heart of the impeller is the one called Supporting Body, which is a casting. All the 23 blades are fixed on to individual shafts which are supported in the supporting body by bearings. The other end of the shaft receives a lever through key joint. All the levers are connected to a disc through jewel bearings which help in transferring the axial movement of the disc into a rotary movement of the blade shafts and hence the blades.

5.4.4 Servomotor Assembly

A Hydraulic Servomotor fixed on to the impeller hub on the discharge side helps in achieving the actuation of the blades. The servomotor consists of a piston and cylinder assembly with control slide and control spool. These are externally controlled by an oil system and electric servomotor with proper linkages.

5.4.5 Diffuser Assembly

The diffuser is a completely welded structure with a core inside. This helps in converting the Kinetic Energy into Pressure Energy. The linkages for the Servomotor are taken through eyes provided on the diffuser. Outlet blades are also housed inside the diffuser. Actually the diffuser core is supported by the outlet blades on the in `let side of the diffuser and by the struts on the discharge side of the diffuser. There is a manhole provided for attending to the servomotor linkages etc.

6. PARAMETERS FOR FANS

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The various parameters of the fans are as follows :

1. Volume (flow rate) Q m^3/s
2. Differential Pressure ΔP mm Wc
3. Temperature T °C
4. Density of Medium γ kgf/m^3
5. Medium Handled.

The units for the parameters have to be converted to the above standard forms it given in other forms for better understanding and selection purposes.

7. CONTROLS

Different types of controls employed for fans can be listed as :

(1) Damper control

(2) Inlet guide vane control

(3) Speed control

(4) Blade pitch control

7.1 Damper Control

This is the least efficient of all the controls. It is actuated by a power cylinder or electrical servomotor

7.2 Inlet Guide Vane Control

This control is used invariably in Axial impulse type (AN) fans and radial fans. This is more efficient than damper control.

7.3 Speed Control

7.3 Speed Control

This is achieved either by a variable speed motor or Hydraulic coupling.

As $Q \propto ND^3$ and
$H \propto N^2 D^2$

the variation in speed varies the performance. With variable speed motors the speed can be varied in some regular steps whereas the hydraulic coupling helps in getting infinite number of speeds right from 20% to full speed.

7.4 Blade Pitch Control

This is the most efficient of all the controls. The impeller blades are tilted during operation and hence the angle of entry is varied to vary the performance. The hydraulic servomotor explained in a previous section helps in achieving the control with. the help of an external oil system.

8. ACCESSORIES

For different applications some accessories have to be supplied for the fans. They may be classified as :

- 8.1 Oil System
- 8.2 Silencer
- 8.3 Slow Turning Mechanism
- 8.4 Cooling System

8.1 Oil System

External Forced oil systems are given for AP fans and radial fans used in PA, ID and GR applications

In AP fans the system is used both for Control and Lubrication.

In Radial fans (PA, ID & GR) the system is used for lubrication purposes.

The system as a whole is a compact unit with necessary pumps, motors, instruments etc.

8.2 Silencer,

Inlet silencers are given for FD and PA tans where the noise level is exceeding the recommended value as per International standards. For each size and type of fan silencers are designed.

8.3 Slow Turning Mechanism

For fans operating at very high temperatures (more than 300 to 350 $^{\circ}$C) a slow turning mechanism is provided to rotate the rotor slowly in case there is total failure of AC supply or even during a shut down. This is to avoid sagging of the hot shaft.

8.4 Cooling System

For ID fans of Axial impulse type a cooling tube is provided to cool the inner bearing. If necessary a cooling fan also may be provided to force air through the cooling tube if relatively cold air in the tube is likely to cause corrosion. This is possible in boilers where oil of high sulphur content is used.

9. INTERLOCK REQUIREMENTS

There are sufficient interlocks provided for the safety of the machines and also for operation. Some are for starting, some for alarm and trip.

The inlet and outlet dampers have to be closed as also the control vanes while starting.

For Bearing temperatures high i.e. > 95 $^{\circ}$C there is alarm and > 105 $^{\circ}$C there is trip for all the fans.

There are separate interlocks for AP fans and also for fans with hydraulic coupling for operation and safety in addition to the interlocks on Motors.

10. CONCLUSION

Equipment once handed over to the Customer should be maintained in the best possible manner. Failures have occurred due to not adhering to the instructions given. Hence it is not just enough to have a good machine without proper maintenance. For that, continuous monitoring system has to, be provided. For example vibration levels, temperature of the bearings etc., have to be periodically checked and noted.

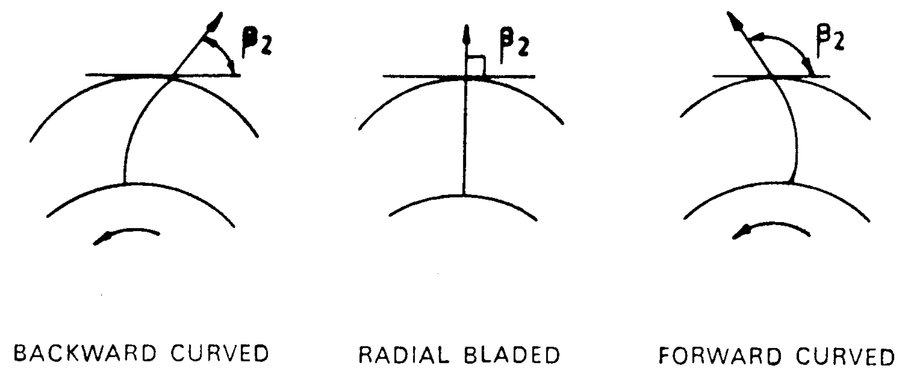

FIG. -1-CONFIGURATION OF BLADE

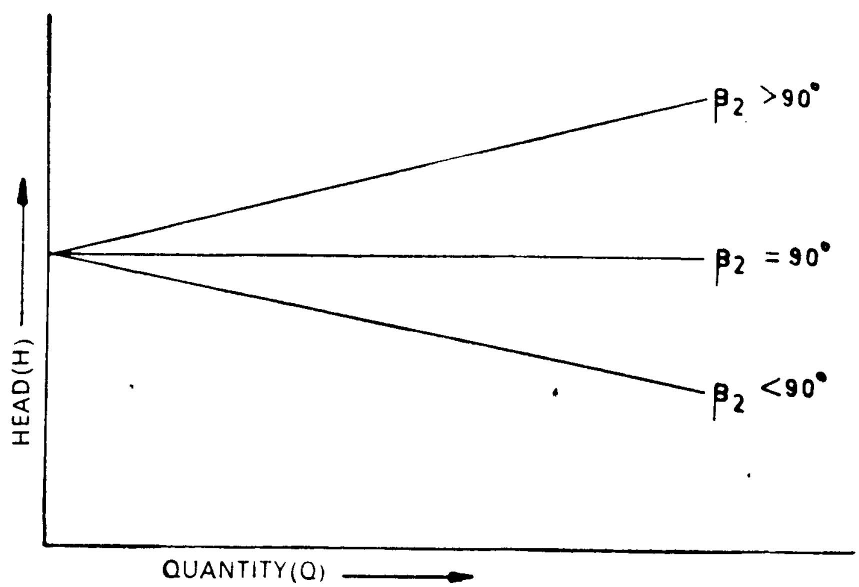

FIG. -2 CHARACTERISTICS OF RADIAL IMPELLERS

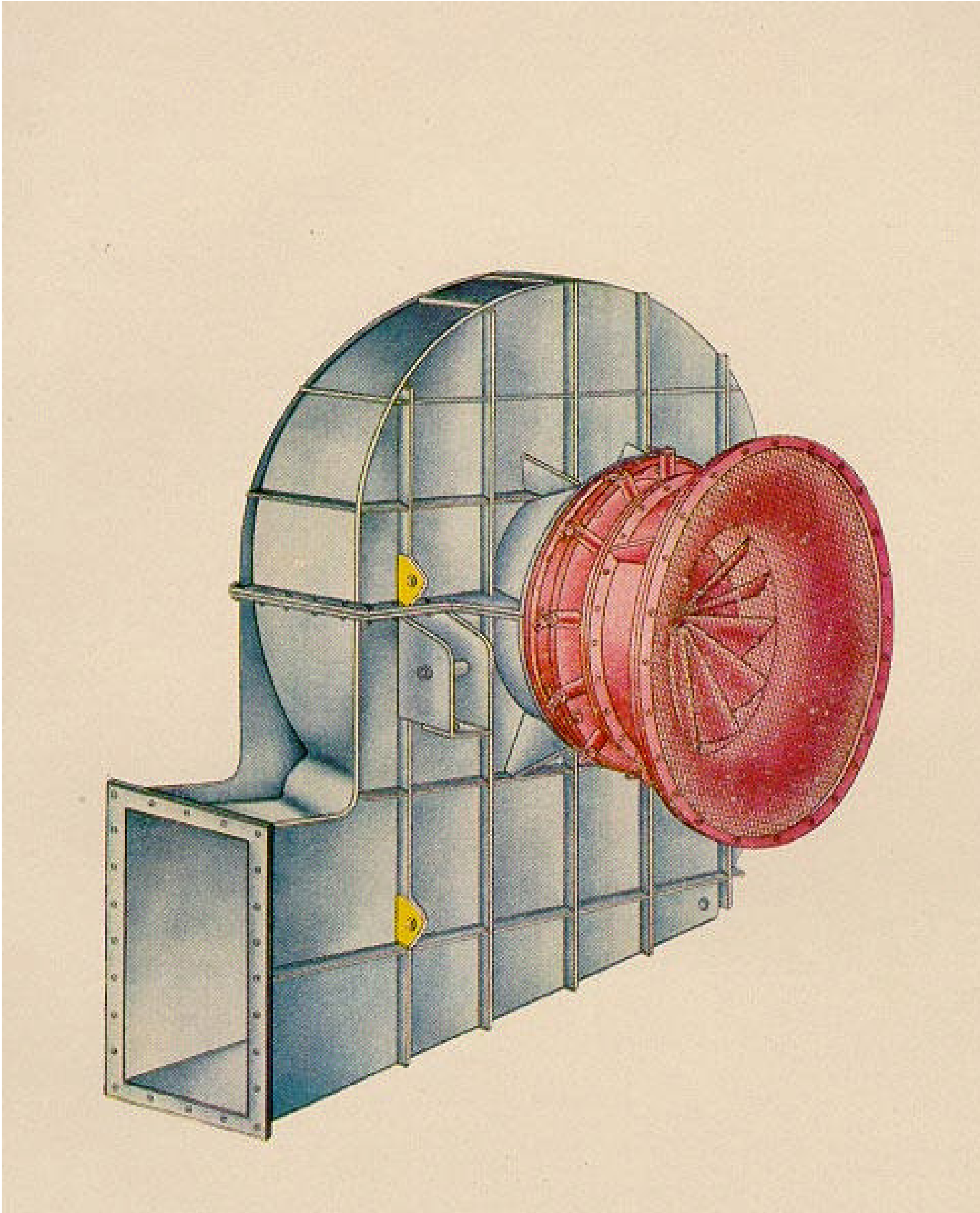

FIG. -3 RADIAL FAN-NDFV

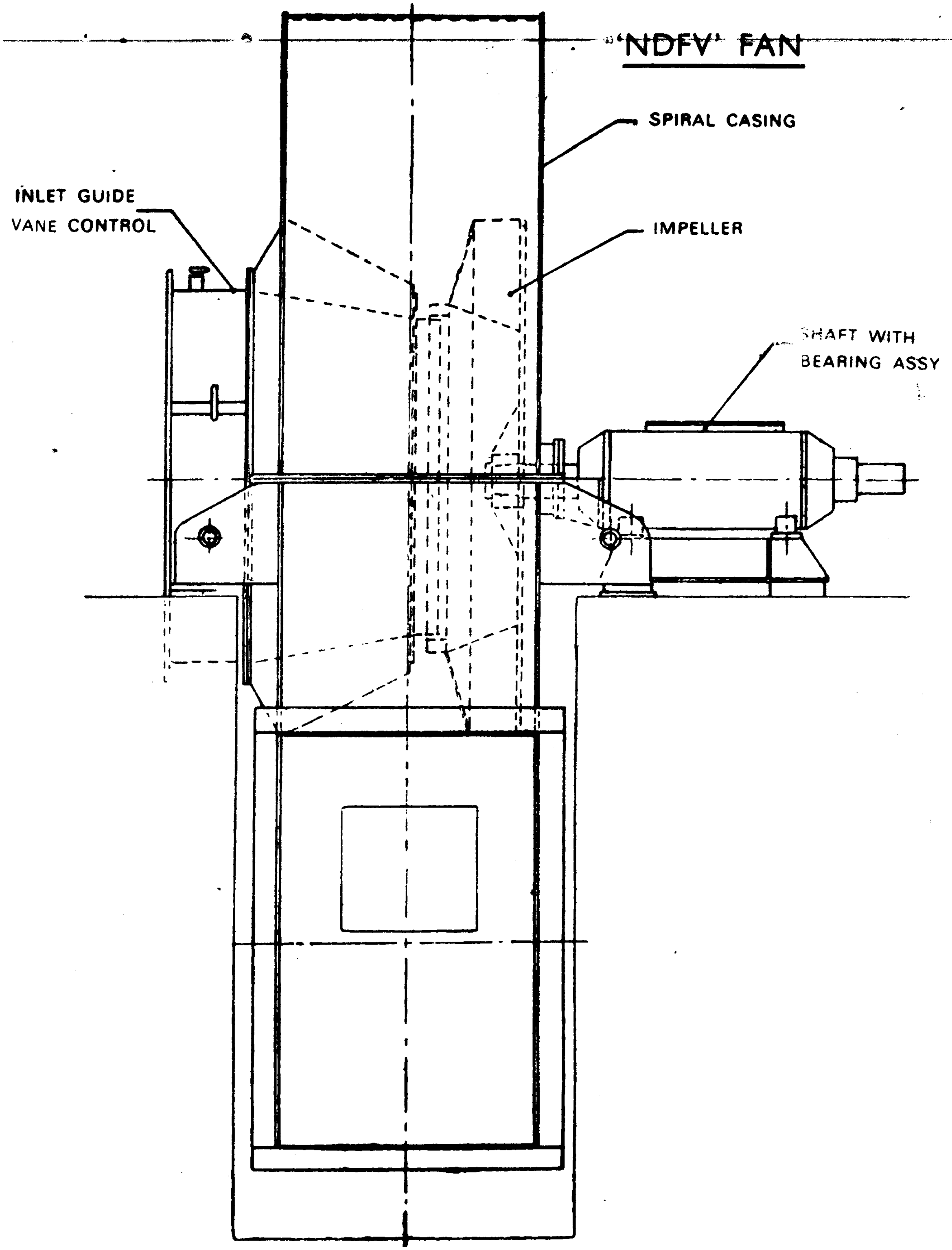

FIG. -3A-NDFV FAN

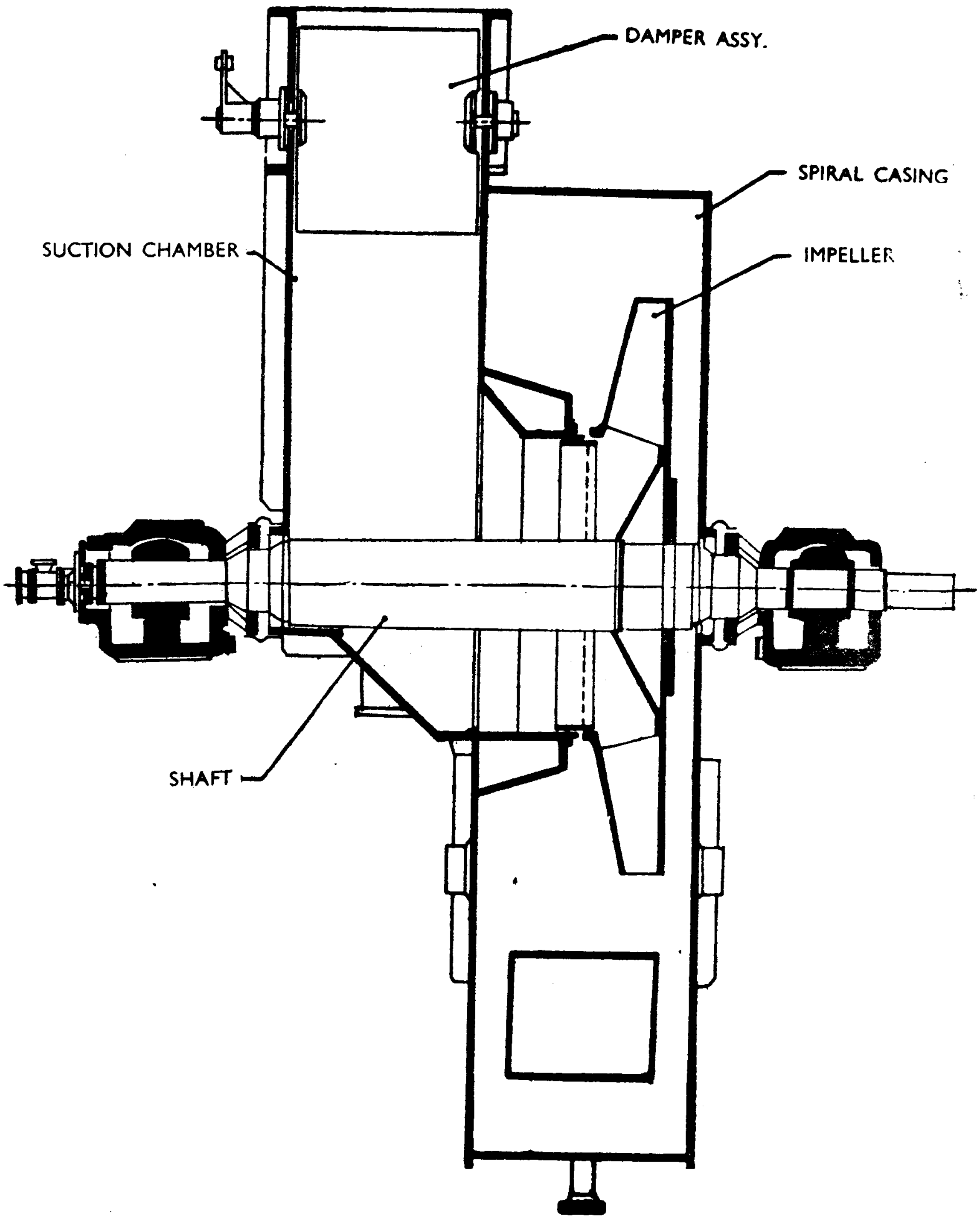

FIG. -4 SINGLE SUCTION RADIAL FAN(NDV)

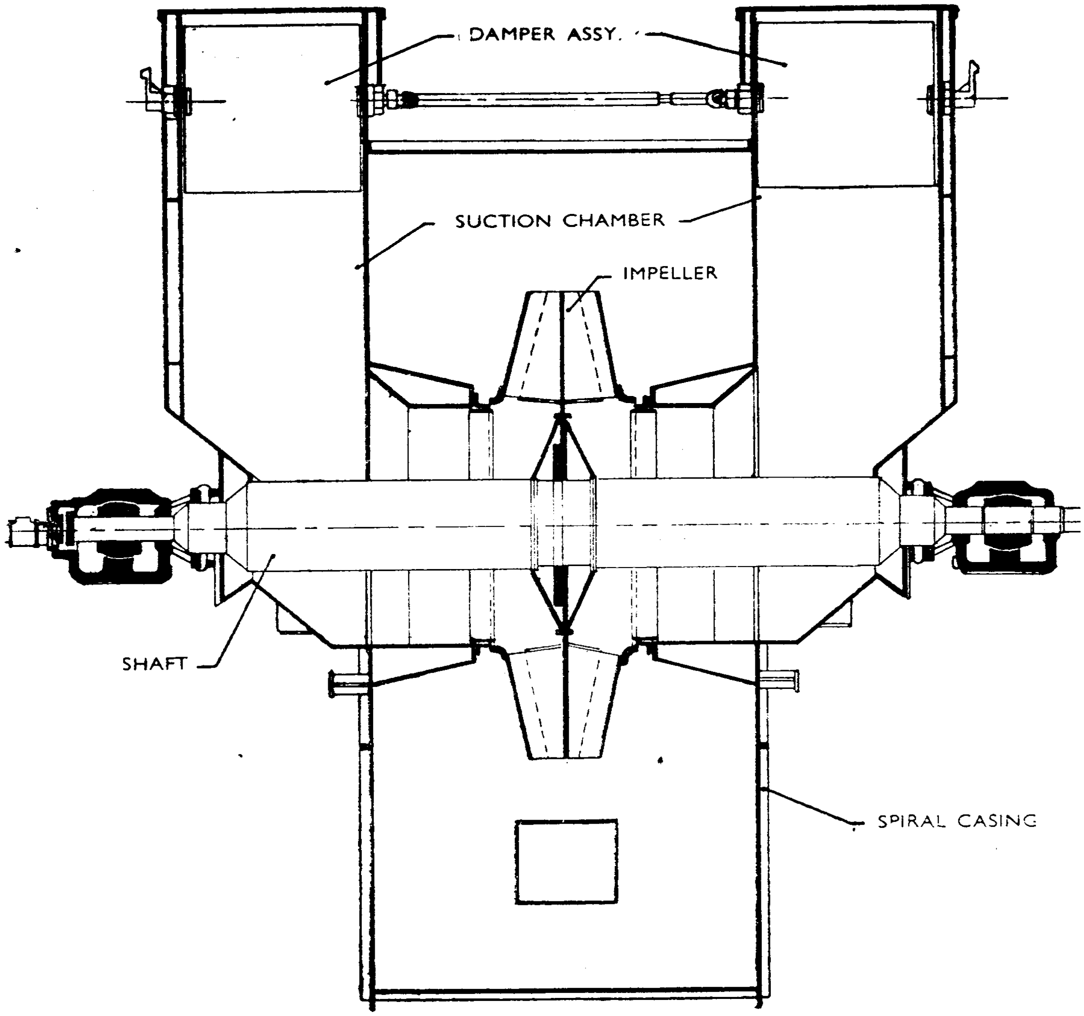

FIG. -5 DOUBLE SUCTION RADIAL FAN (NDZV)

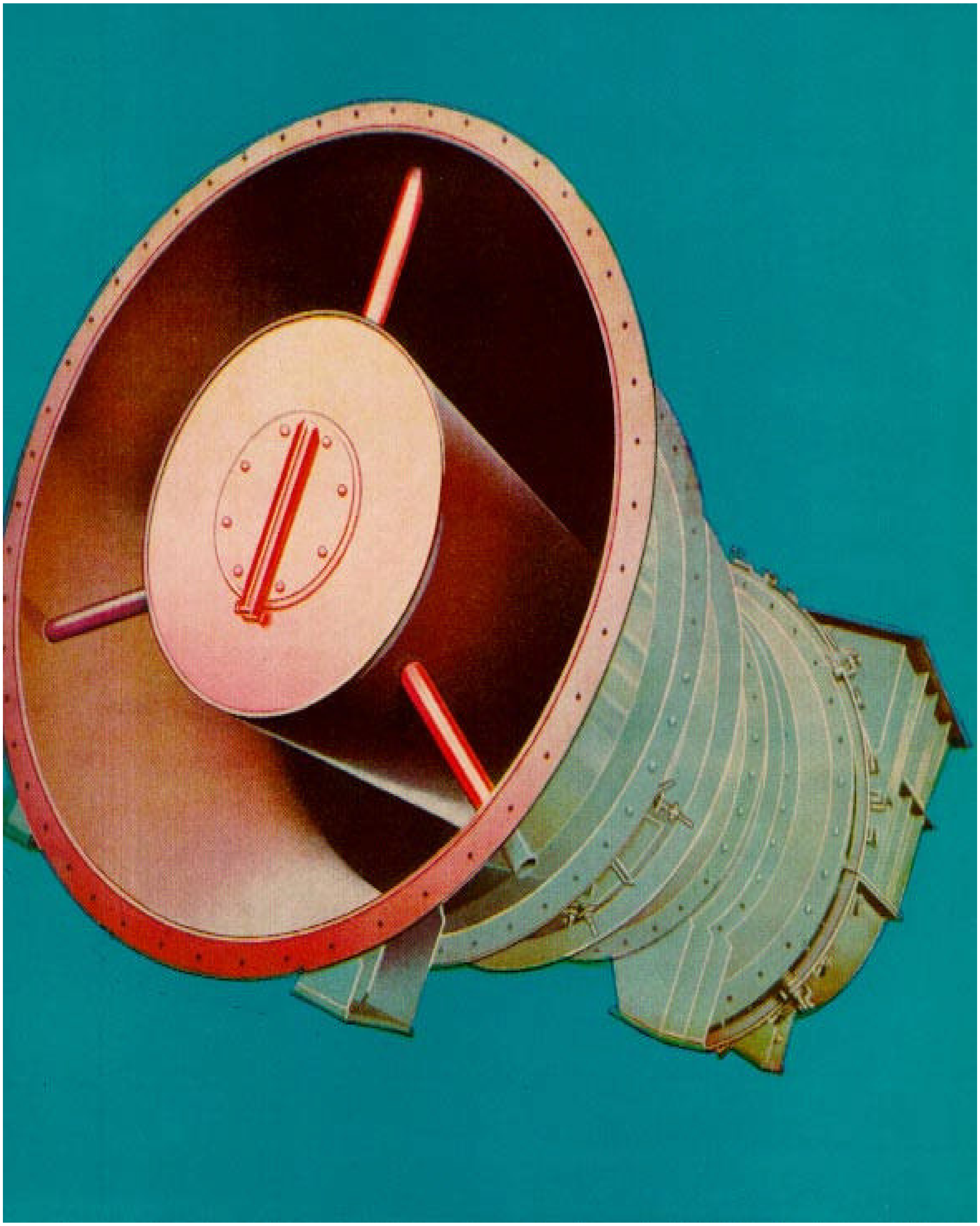

FIG. -6 AXIAL FAN-TYPE IMPULSE AN FAN, SIMPLY SUPPORTED-
APPLICATION FD OR ID FANS

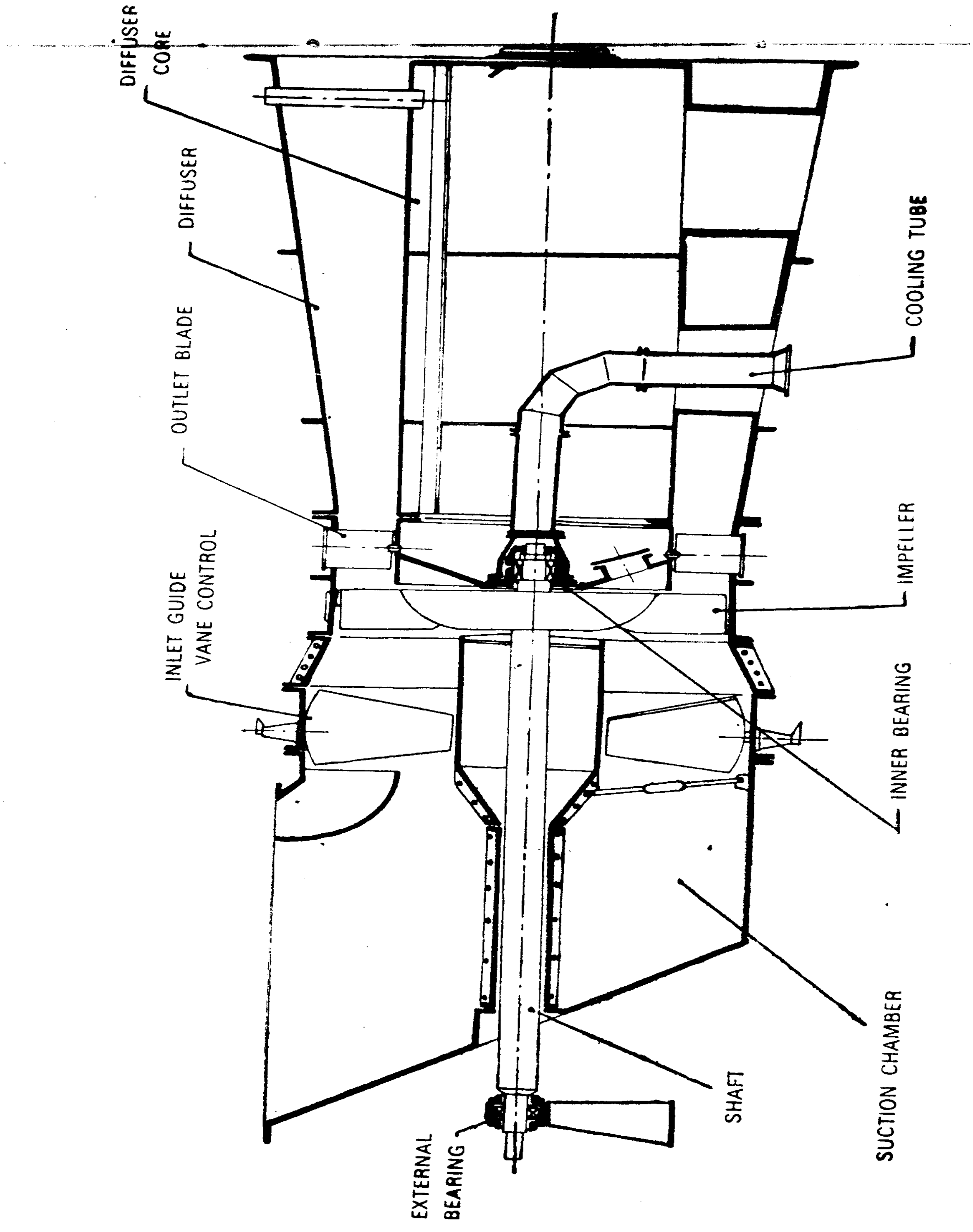

FIG. 7 AXIAL FAN IMPULSE TYPE

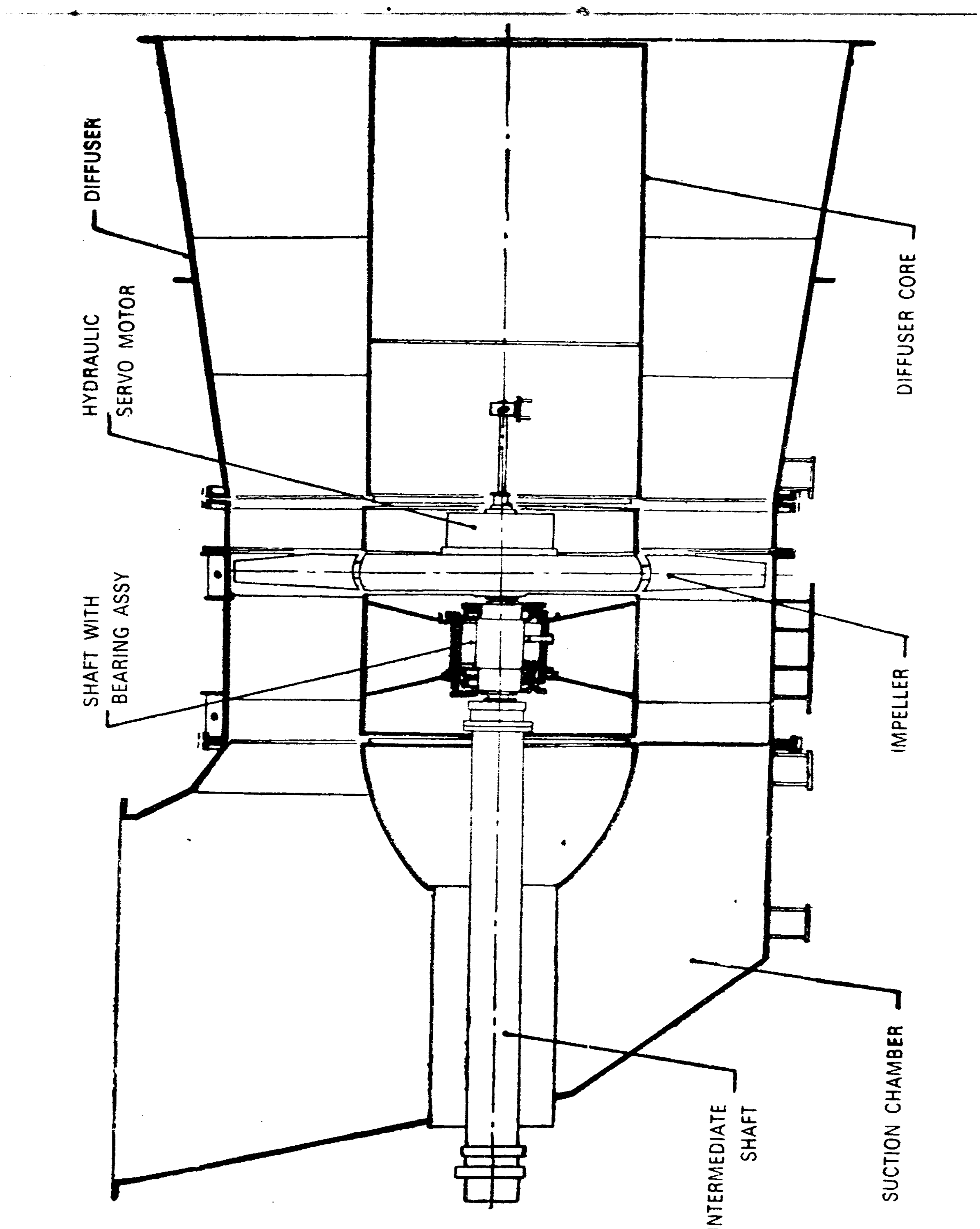

FIG. -8 AXIAL FAN REACTION TYPE (AP)