Flow Rotation Vanes Improve Piping Component Performance

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J. Lloyd Jones has been Vice President, Engineering for Cheng Fluid Systems, Inc. since its formation in 1990. He spent 35 years with NACA/NASA and successively worked in large wind tunnel design, fluid dynamic and aerodynamic research and research management leading to the position of Deputy Associate Administrator for Aeronautics. Following retirement from NASA in 1979, Mr. Jones was involved in the development and commercialization of Cheng Cycle steam injected gas turbines and served as project manager on the first three installations. As Vice President of Rann Inc., he was involved in studies of the aerodynamics and structural dynamics of wind turbines. Mr. Jones has authored over 35 technical reports and papers and is past chairman of NATO-AGARD Fluid Dynamics Panel. He has a Bachelor of Science degree in Aeronautical Engineering from the University of Washington and a Master of Science in Engineering Science from Stanford University.

Cheng Rotation Vanes (CRV®)* consist of a set of vanes, placed just upstream of an elbow in a piping system, as illustrated in Figure 1. The purpose of the vanes is to enable the fluid to negotiate the turn through the elbow without the characteristic flow separation and accompanying large scale turbulence, so that the flow downstream of the elbow is aligned with the pipe centerline and contains little or no cross-stream velocity gradients or turbulence.

Flow Separation Results in Problems

The flow through a plain elbow is illustrated on the left in Figure 2. As a result of the forces acting on the fluid as it passes through the elbow, two flow separation regions result. Because of the existence of these regions, the remaining cross-sectional area through which the fluid must pass is significantly reduced, and the local velocity is increased and directed toward the outer wall of the elbow. This is the reason for severe erosion on the outer wall for two-phase fluids or fluids with particulate matter. The boundary, between the large inner separation region and the high speed core flow, causes shed vortices that are the source of the large scale turbulence. Measured cross-stream velocity profiles from the inner wall at the bottom to the outer wall at the top are shown at the bottom of Figure 2 for six successive stations, each one-quarter of a diameter apart, beginning at the end of the elbow.

Improving Flow with Vanes

The vanes, placed upstream of the elbow, introduce a

10" CRV®

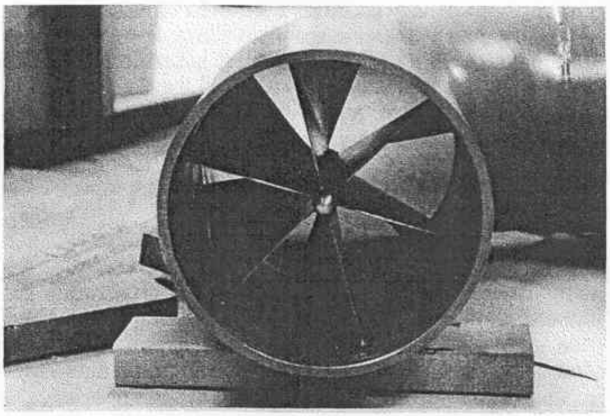
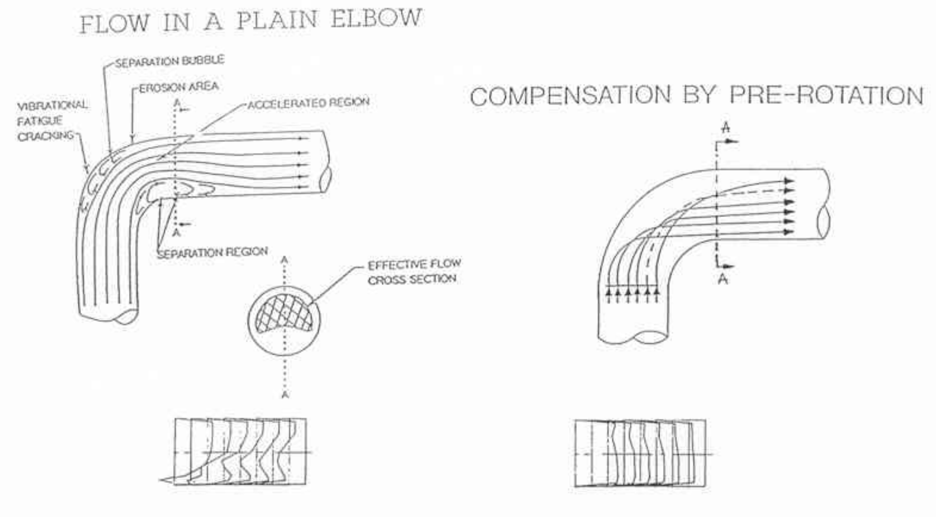


Figure 1

- *INSTALLATION: Double Suction Condensate Pump with Close Coupled 90° Elbow*
- *CONDITIONS: 1950 gpm, 1 psi, Ambient Water*
- *PROBLEM: Pump Cavitates Due to Non-Uniform Inlet Flow*
- *CRV® RESULTS: Provides Uniform Inlet Flow Resulting in:*
  - *Eliminates Cavitation*
  - *Reduces Vibration*
  - *Increase in Overall Pump Efficiency*

THE CRV® ELIMINATES FLOW SEPARATION



VELOCITY PROFILES FOR FIRST 1-1/2 DIAMETERS DOWNSTREAM OF ELBOW EXIT A-A

Figure 2

rotational vector into the entering fluid flow such that it can negotiate the turn with all stream elements travelling the same distance from entrance to exit, as illustrated on the right side of Figure 2. The classic cross flow pattern thus is not developed, nor are the flow separation regions. Cross flow velocity profiles, measured downstream from the elbow exit just as for the plain elbow flow, are shown on the bottom right of the figure. It is seen that the flow separation that existed at the inner wall for the plain elbow case has disappeared, and that by one and a half diameters downstream the velocity profile is very flat.

Case Histories Show Improved Operation & Performance

The experience obtained in field installations has demonstrated that elimination of the flow separation and the attendant turbulence results in greatly improved operation and performance of system components placed downstream of elbows in piping systems. A number of examples are described in the following paragraphs.

1. Reduced Vibration & Increased Performance for Pumps

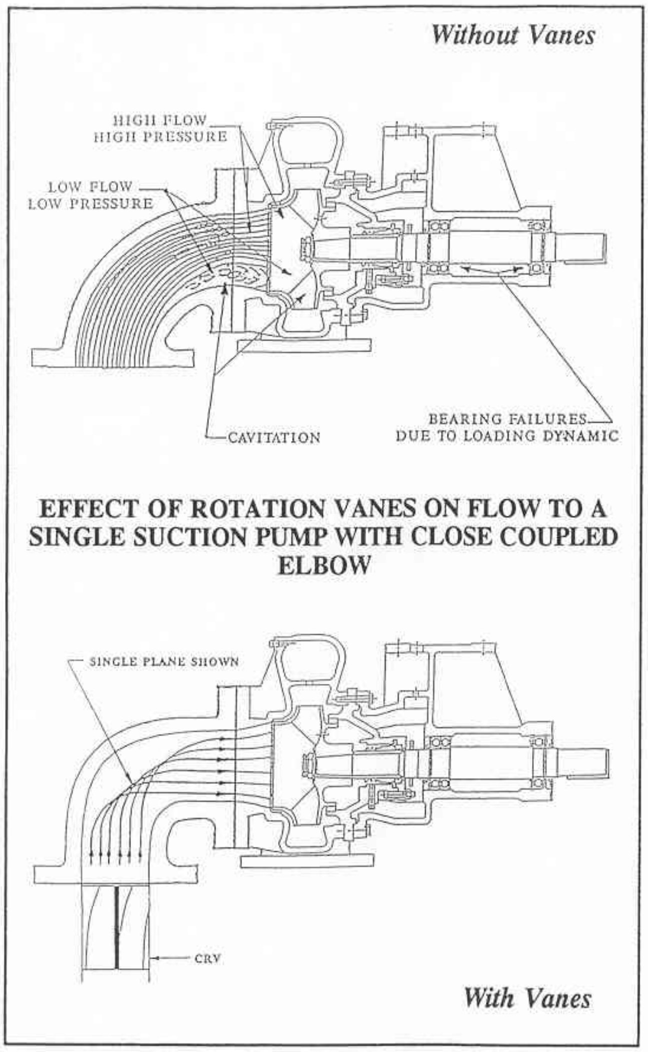
The design of pump impellers assumes a uniform inflow parallel to the pipe centerline. Experience has shown that when the inflow contains cross-stream velocity gradients and large scale turbulence, as found downstream of plain elbows, the resulting pump performance curve differs significantly from the design curve, with lower flow rates and lower discharge pressures.

The use of rotation vanes, upstream of an elbow in a pump suction line, results in low turbulence flow with a radial symmetry approaching the impeller of a single suction pump as shown in Figure 3 and in the pump operating close to the design performance curve. The situation is similar for a double suction pump, as shown in Figure 4, except that without the vanes, most of the low energy, highly turbulent fluid enters the duct for one impeller and the high energy flow with low turbulence enters the other duct. The result is poor performance and high vibration for the one impeller and high performance for the other. This situation results in an imbalance of the thrust of the two impellers, a high level of vibration, and dynamic loads on the thrust bearings for which they were not designed.

Field installations for both single and double-suction pumps have resulted in greatly reduced vibration and noise plus higher flow rate, discharge pressure and pump efficiency. Recent attention has been directed to applying the vanes to magnetic drive zero-emission pumps as indicated in Figure 5. The situation here is essentially the same as for standard single-suction pumps: The pumps were in use in a chemical company plant. After the installation of the vane units, the user reported that the cavitation and vibration was eliminated and an increase in flow of 7% was measured.

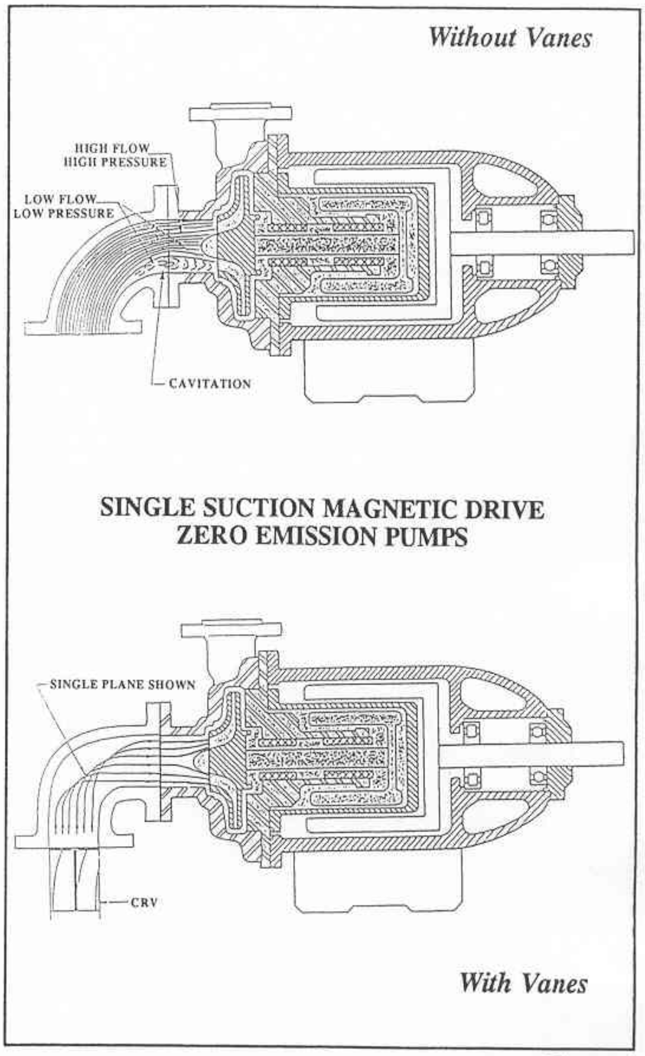
2. Reduced Meter-Runs in Flow Metering Applications

Straight pipe meter runs, as long as 30 diameters, are recommended by flow metering instrument suppliers. The installation of straightening vanes in the straight pipe ahead of the instrument can reduce the required straight pipe run somewhat, as shown in Figure 6. The installation of rotation vanes, ahead of the elbow in the pipe line, is also shown in Figure 6. Because of the uniform flow profiles at the elbow exit when it is preceded by rotation



EFFECT OF ROTATION VANES ON FLOW TO A SINGLE SUCTION PUMP WITH CLOSE COUPLED ELBOW

Figure 3



SINGLE SUCTION MAGNETIC DRIVE ZERO EMISSION PUMPS

Figure 5

Effect of Rotation Vanes on Flow to a Double Suction Pump

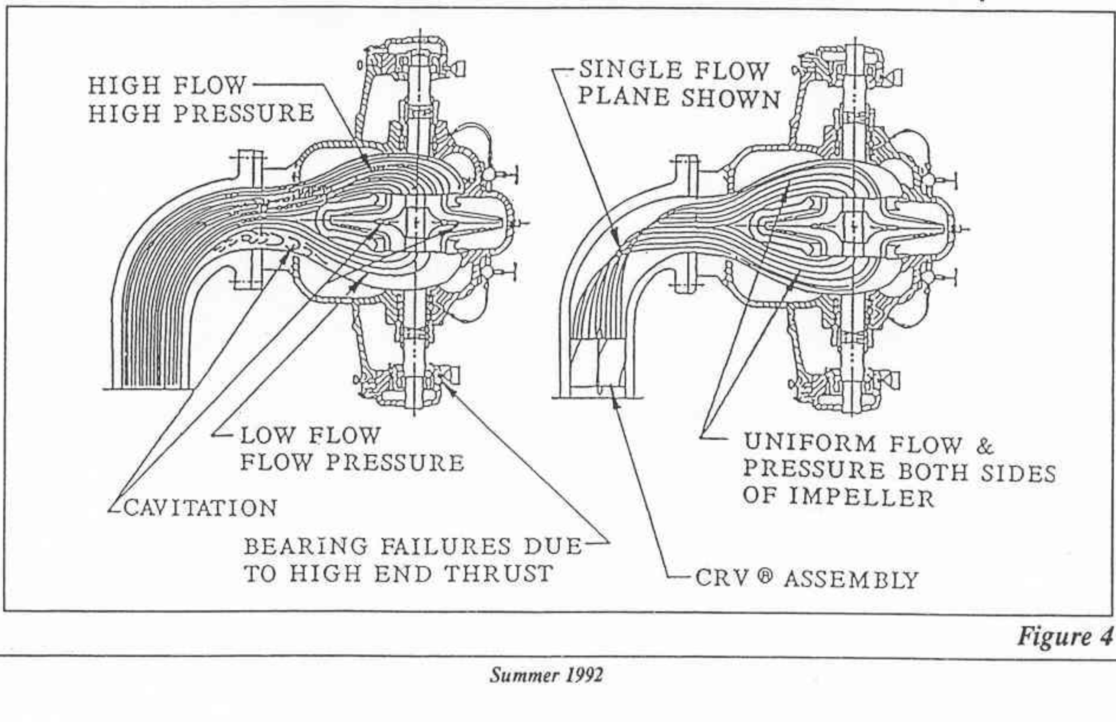


Figure 4

Three Examples of Meter Runs Required

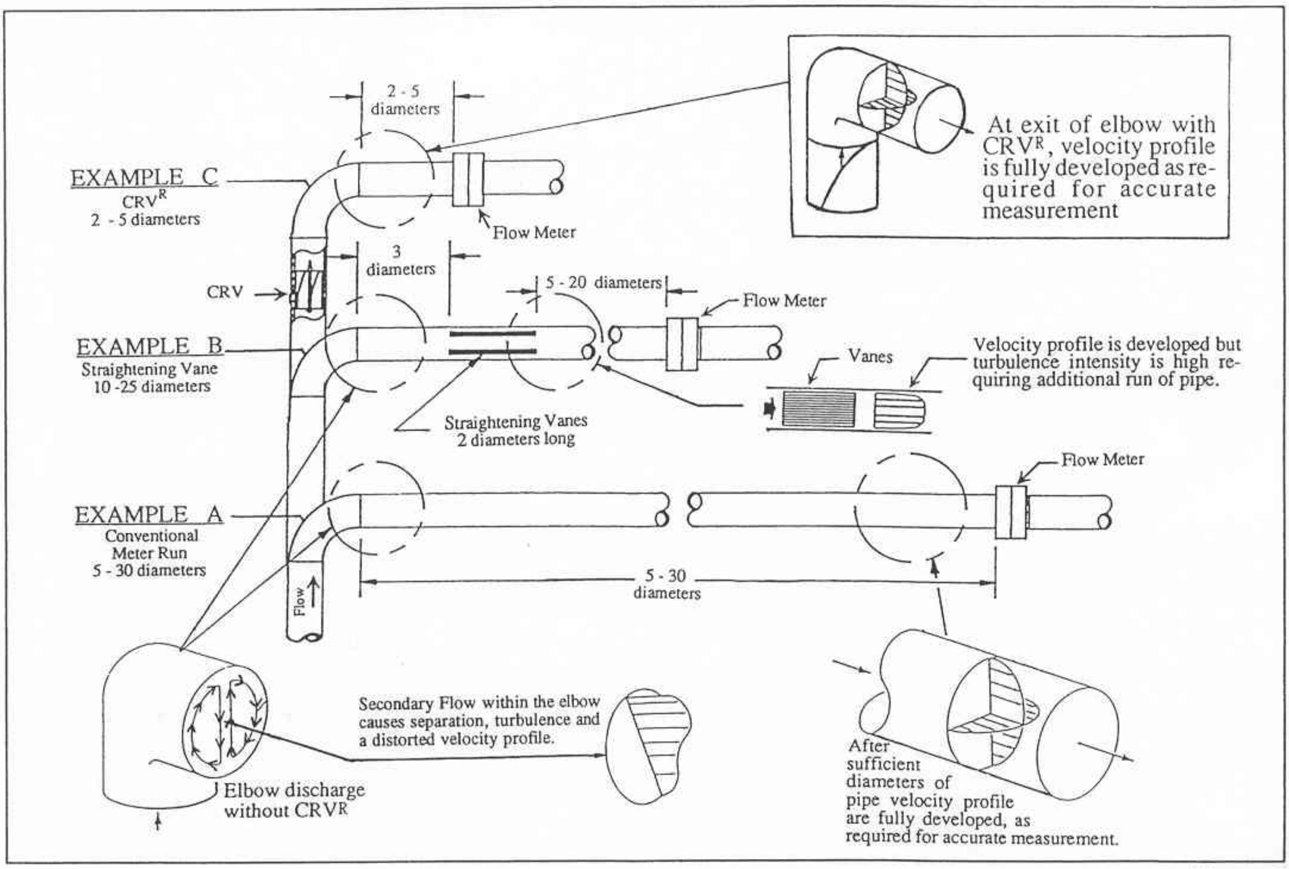


Figure 6

vanes, long meter runs are not required to obtain good flow measurements. The required meter run for such an installation is reduced to 5 diameters or less as also shown in Figure 6.

The advantages from the use of rotation vanes in metering run applications are important because it is seldom convenient to provide a 20 to 30 diameter straight pipe meter run. To illustrate, 18-inch vane units are now installed in a refinery ahead of flow metering instruments. This type of installation will result in the saving of 25 diameters of straight pipe meter run, or 38 feet of 18-inch pipe. In plants where only a short meter run was provided, installation of vanes will result in more accurate measurements.

3. Erosion Reduction

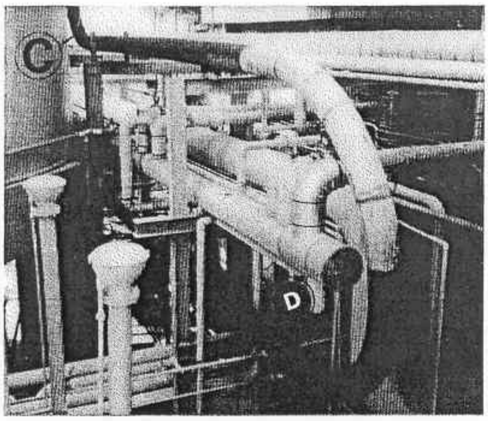
Elbows (turns) are known to be critical points in piping systems for erosion damage from two-phase flows (such as wet steam) or from flows carrying particulate matter. The reason may be seen by referring back to Figure 2. The accelerated flow, directed toward the outer wall of the elbow, acts as a nozzle focusing high speed droplets or particles on a restricted region. Elimination of the flow separation, with the resulting uniform velocity plus the vane induced swirling flow, assures that droplets or particulates are borne along with the flow much as in the straight pipe runs.

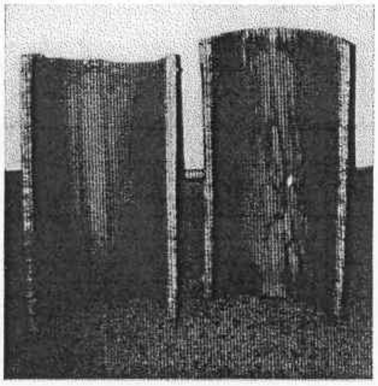
Installations for wet steam lines in paper mills, for 2-inch extra-heavy pipe lines, are still in successful operation 15 months after installation where elbow replacement previously was required every 3 months. Ten-inch diameter vane units have been supplied to one refinery for installation in a FCCU spent catalyst blowdown line with large diameter turns. A photo of one section of the line is shown in Figure 7. An example of the erosion experienced in this line without vanes is shown at the lower right side of Figure 7.

4. Improving Compressor Performance

The operation and performance of a compressor is sensitive to the uniformity of the velocity distribution and the turbulence of the approaching flow as is that of a pump. The first commercial installation of rotation vanes was to eliminate the turbulence and velocity gradients that resulted from an elbow upstream of the 12-inch intake line on an air conditioning system compressor. The fluid was chilled ambient air, drawn through a copper tube freon heat exchanger. Reported results measured a 50% reduction in inlet pressure drop, coinciding with uniform cooler freon flow. The operation of the compressor was quieter, the vibration was reduced, and a sizeable improvement in compressor efficiency was achieved.

Larger compressors are used in fluid catalytic cracking units at petroleum refineries and in chemical plants.





Example of Eroded Catalyst Blow Down Elbow (Notice hole eroded through)

Figure 7

Upstream turns in the air intake lines of such compressors result in non-uniform flow profiles approaching the first stage rotor as is illustrated in Figure 8. The highly turbulent and non-uniform compressor entrance-air velocity profile is indicated at the right of the Figure 8. Such an entering airflow profile makes it more difficult to achieve a uniform entrance flow around the impeller disc.

In this case, it is possible to install rotation vane units just ahead of the 180-degree turn and at the bottom center turn segment with the access port. The result will be a low turbulence, uniform velocity profile entering the compressor case, as well as increased discharge pressure and flow rate. Experience to date indicates that an increased flow rate and discharge pressure of 5% to 10% is achievable.

Cheng Rotation Vanes have successfully eliminated flow separation and the attendent turbulence in piping elbows. The case histories discussed have given practical examples in which the application of these vanes has resolved piping systems' operational problems resulting from elbow flow separation. ◇

**CRV®, Cheng Rotation Vanes, are a patented technology of Cheng Fluid Systems, Inc.*

Additional information may be obtained by contacting, Cheng Fluid Systems Inc., 259 San Geronimo Way, Sunnyvale, CA 94086, Phone: (408) 720-8657, FAX: (408) 720-0166.

Turn in Entrance Air Lines for Large Compressors

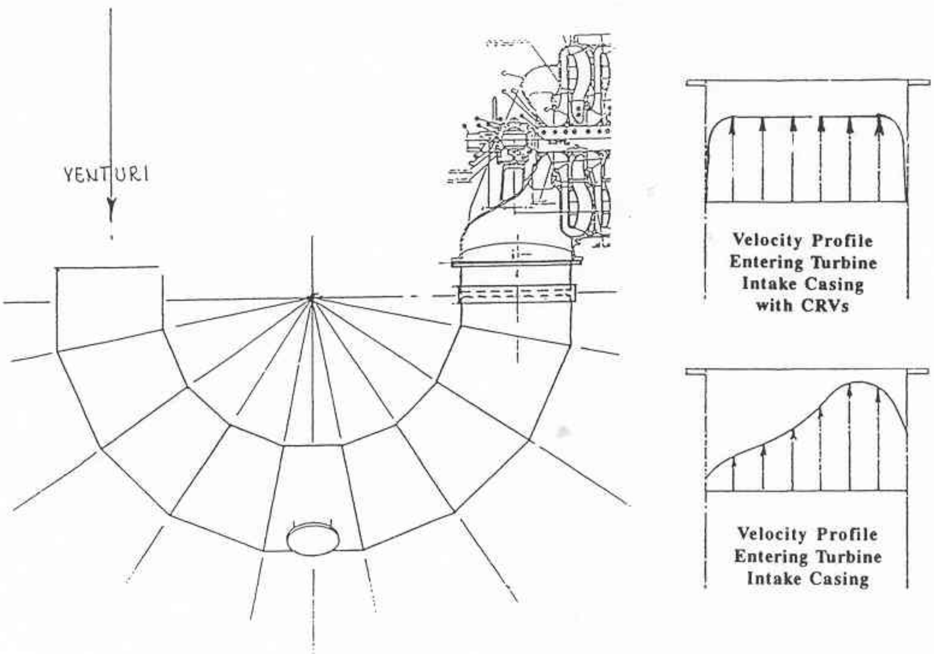


Figure 8