

FUERZAS EN BOMBAS CENTRÍFUGAS

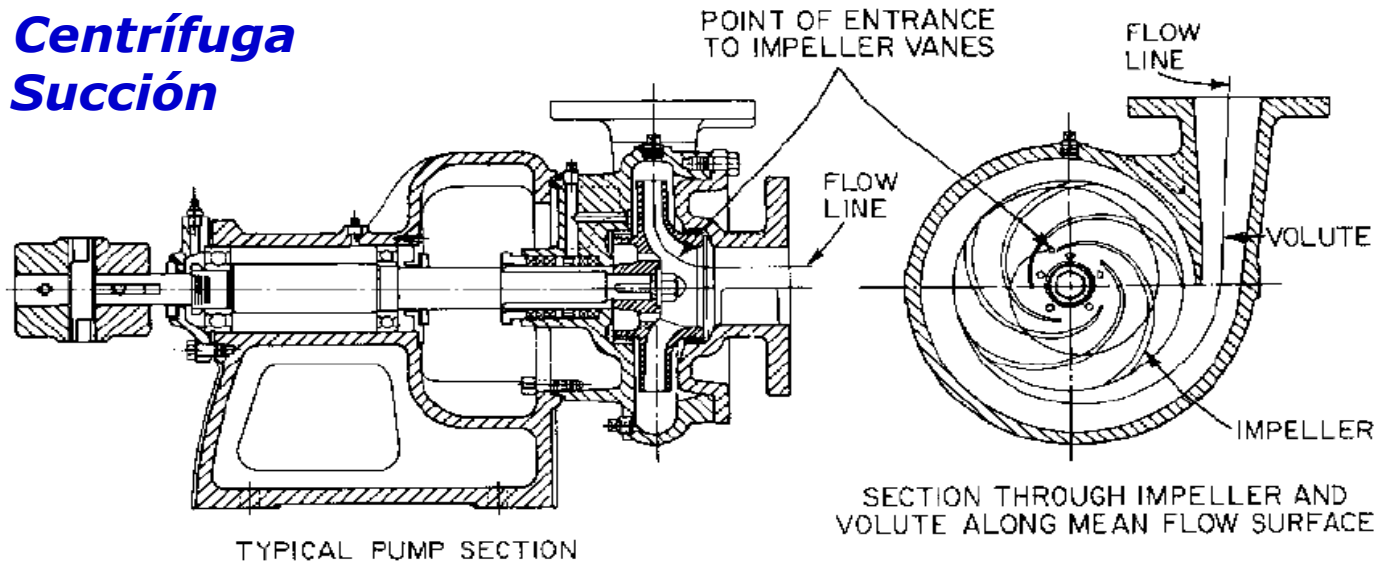
Prof. Jesús DE ANDRADE

Prof. Miguel ASUAJE

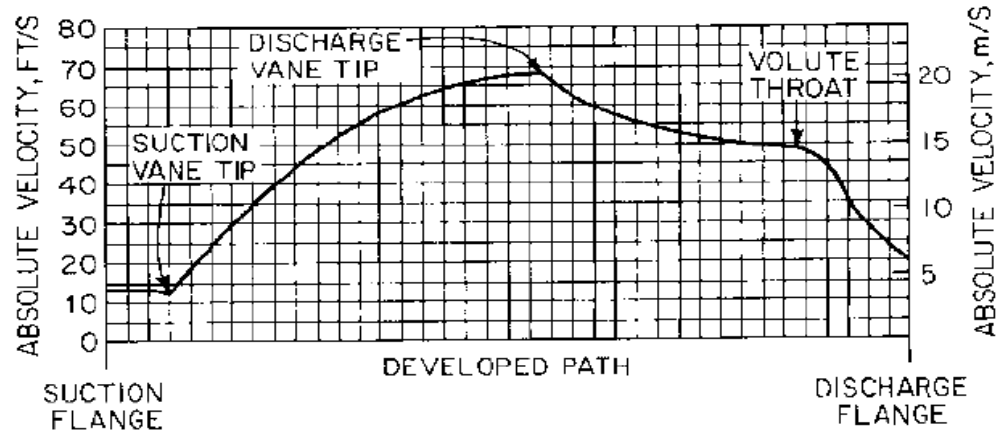
Febrero 2010

Bomba Centrífuga Rodete Simple

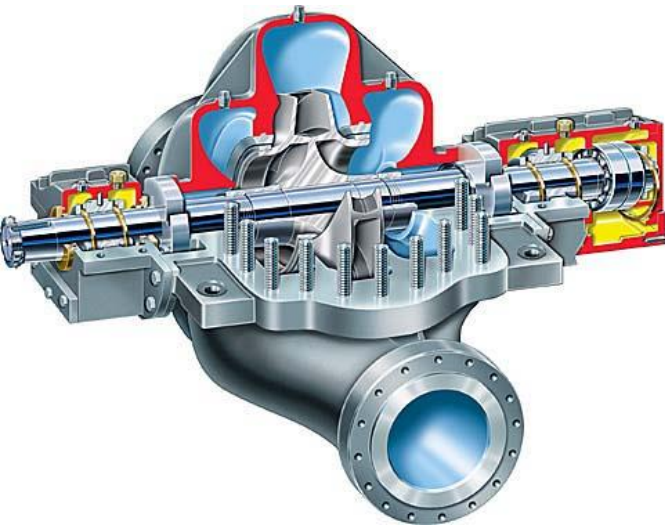
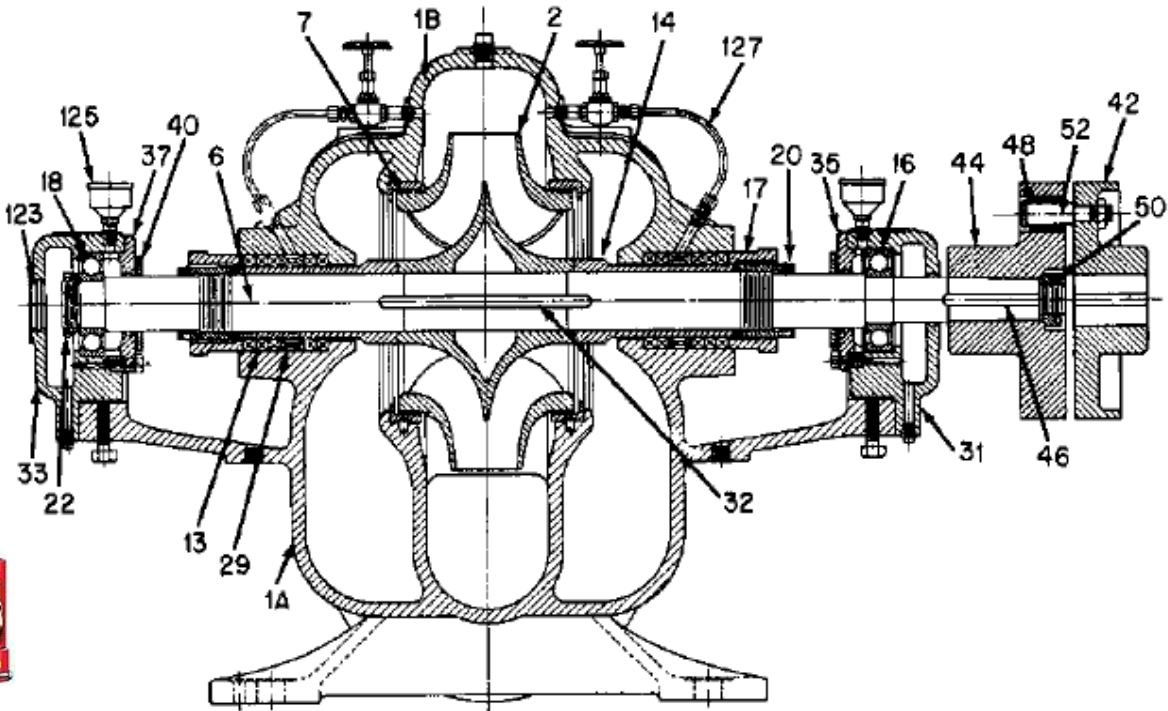
Bomba Centrífuga Simple Succión



200 GPM (45.5 m³/h)
 166 FT (50.6 m) TOTAL HEAD
 3,500 RPM
 2 1/2 IN (63.5 mm) SUCTION DIAM.
 2 IN (50.8 mm) DISCHARGE DIAM.
 6 3/4 IN (171.5 mm) IMPELLER DIAM.
 8/16 IN (15.9 mm) IMPELLER WIDTH

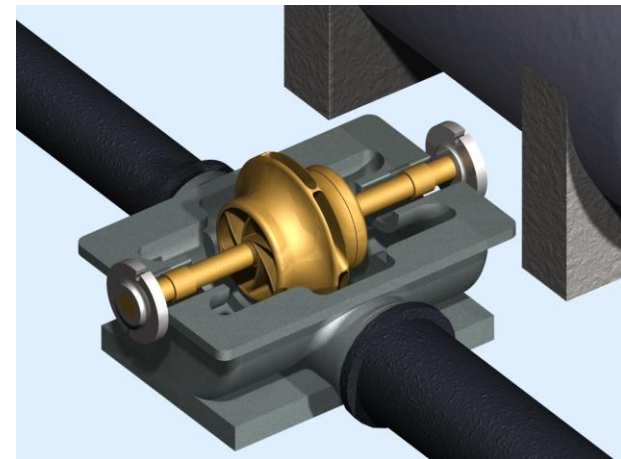
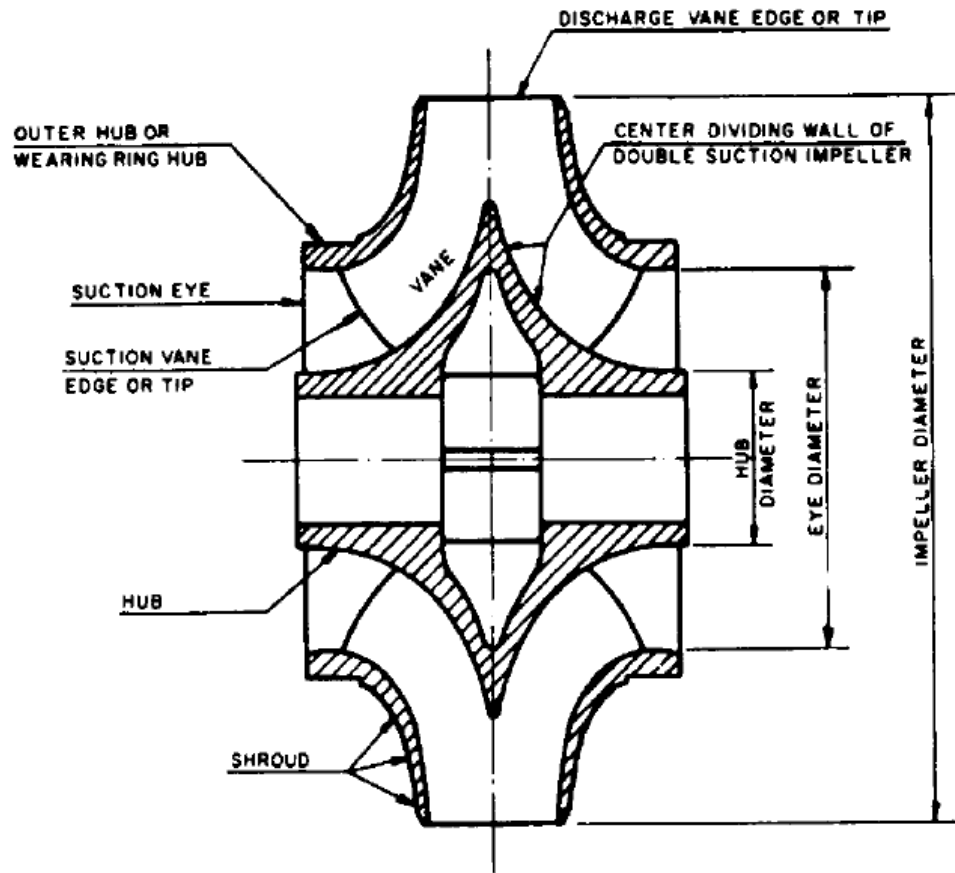


Bomba Centrífuga Doble Succión

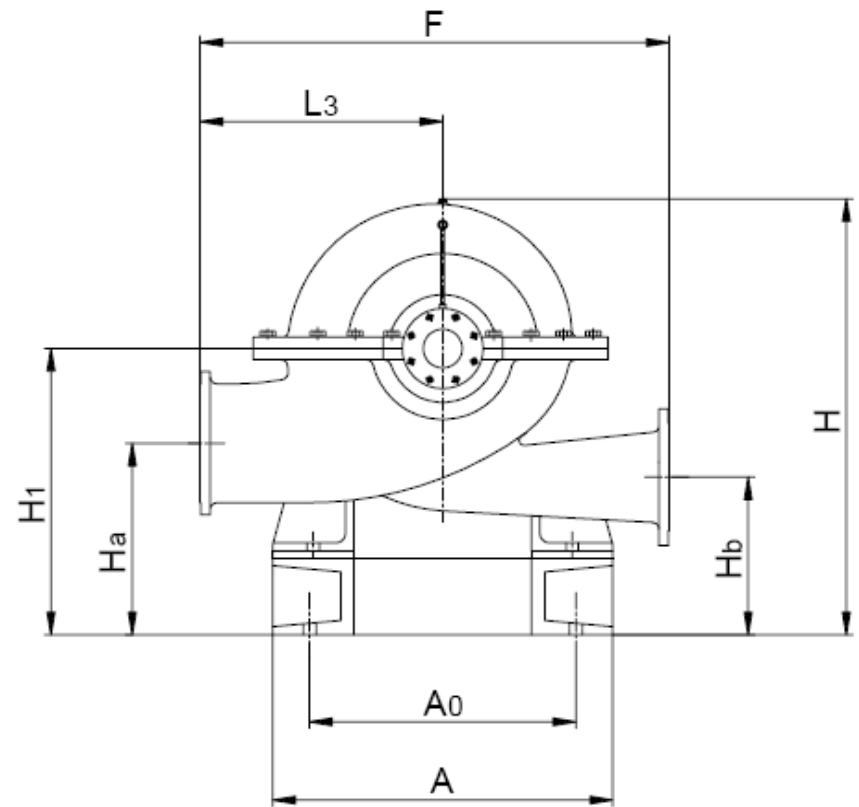
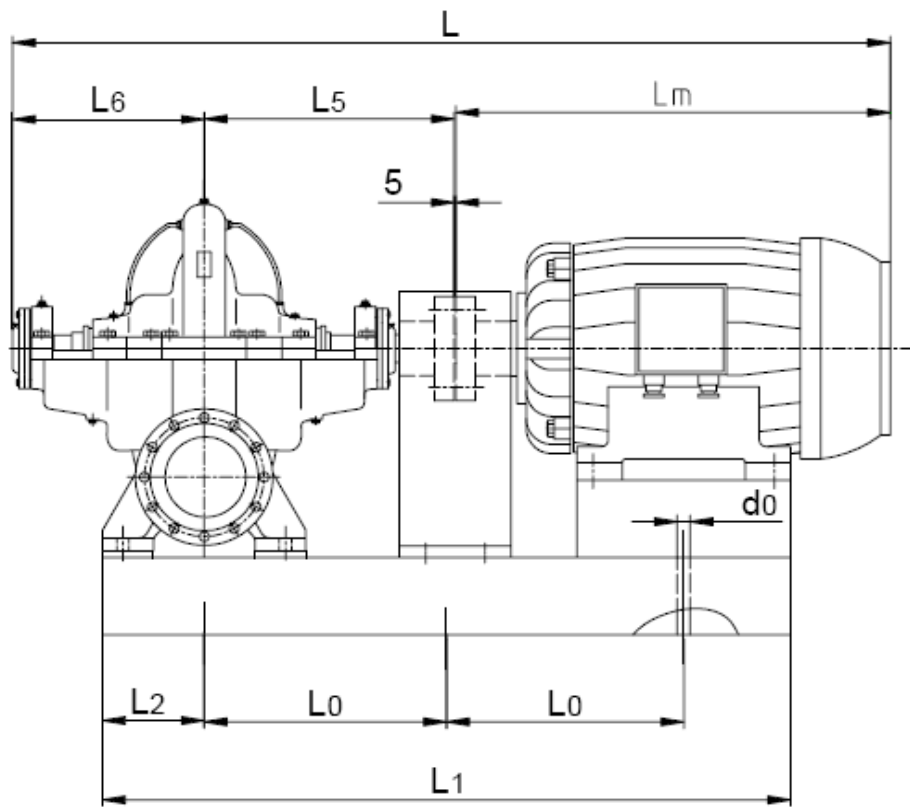


Bomba Centrífuga Doble Succión

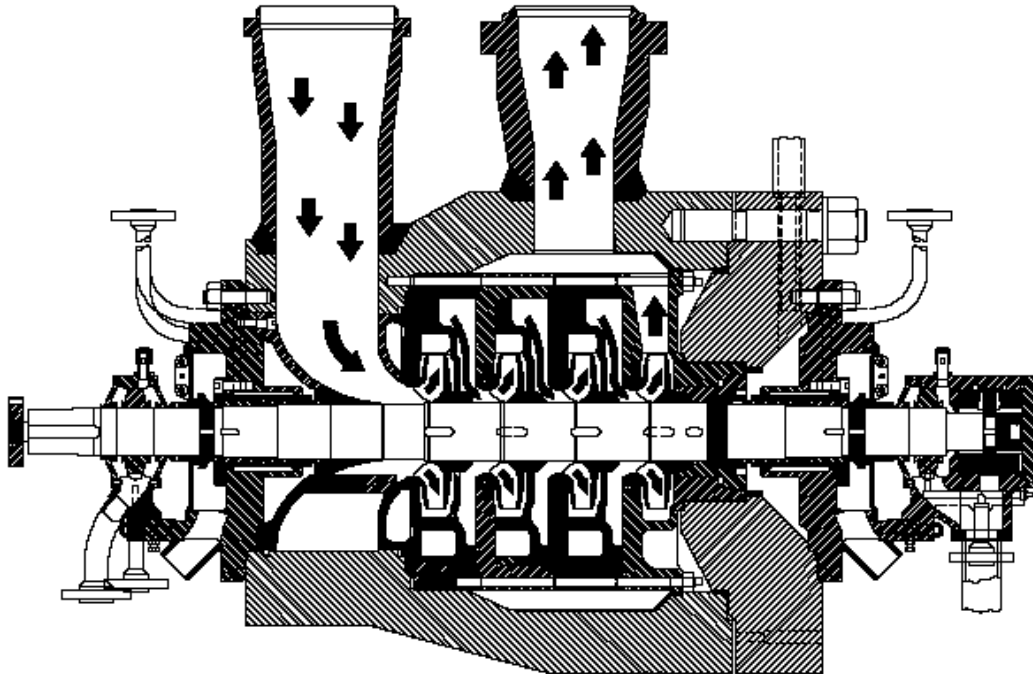
Un detalle en el rotor doble



Bomba Centrífuga Doble Succión

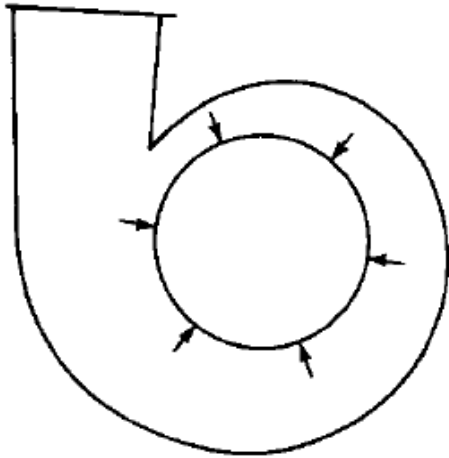


Bombas multietapas



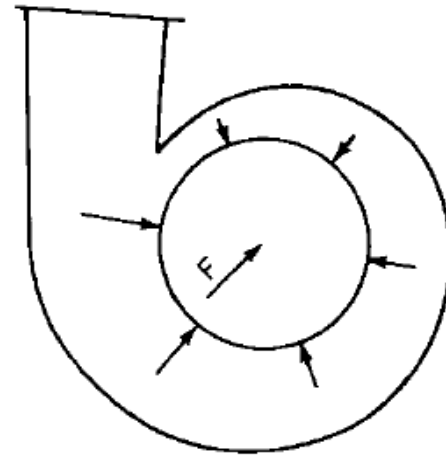
Empuje Radial

Fuerzas Radiales sobre el Rodete



A Caudal Nominal

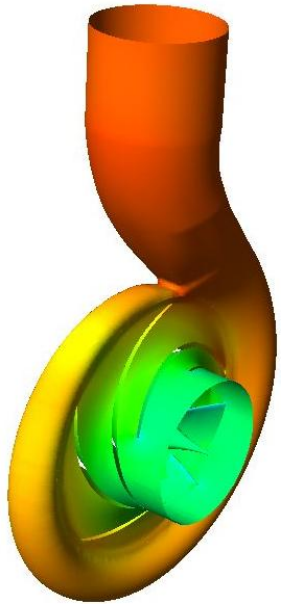
$$\sum F_p \approx 0$$



Fuera del Caudal Nominal

$$\sum F_p \neq 0$$

*Campos de Velocidad y Presión
dentro de una Bomba Centrífuga
Obtenidos por Mecánica de
Fluidos Computacional (CFD)*



CFD ó Métodos 3D ...

Masa $\frac{\partial \rho}{\partial t} + \vec{\nabla} \cdot \rho \vec{C} = 0$

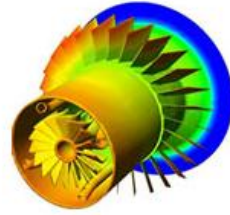
*Cambio de
Cantidad de
Movimiento* $\rho \frac{D\vec{C}}{Dt} = \rho \left[\underbrace{\vec{C} \cdot \vec{\nabla}}_{(2)} \cdot \vec{C} + \underbrace{\frac{\partial \vec{C}}{\partial t}}_{(3)} \right] = -\underbrace{\vec{\nabla} p}_{(4)} + \underbrace{\rho g}_{(5)} + \underbrace{\vec{\nabla} \cdot \tau_{ij}}_{(6)}$

Energía $\rho \frac{Dh}{Dt} = \frac{Dp}{Dt} + \vec{\nabla} \cdot \lambda \vec{\nabla} T + \Phi$

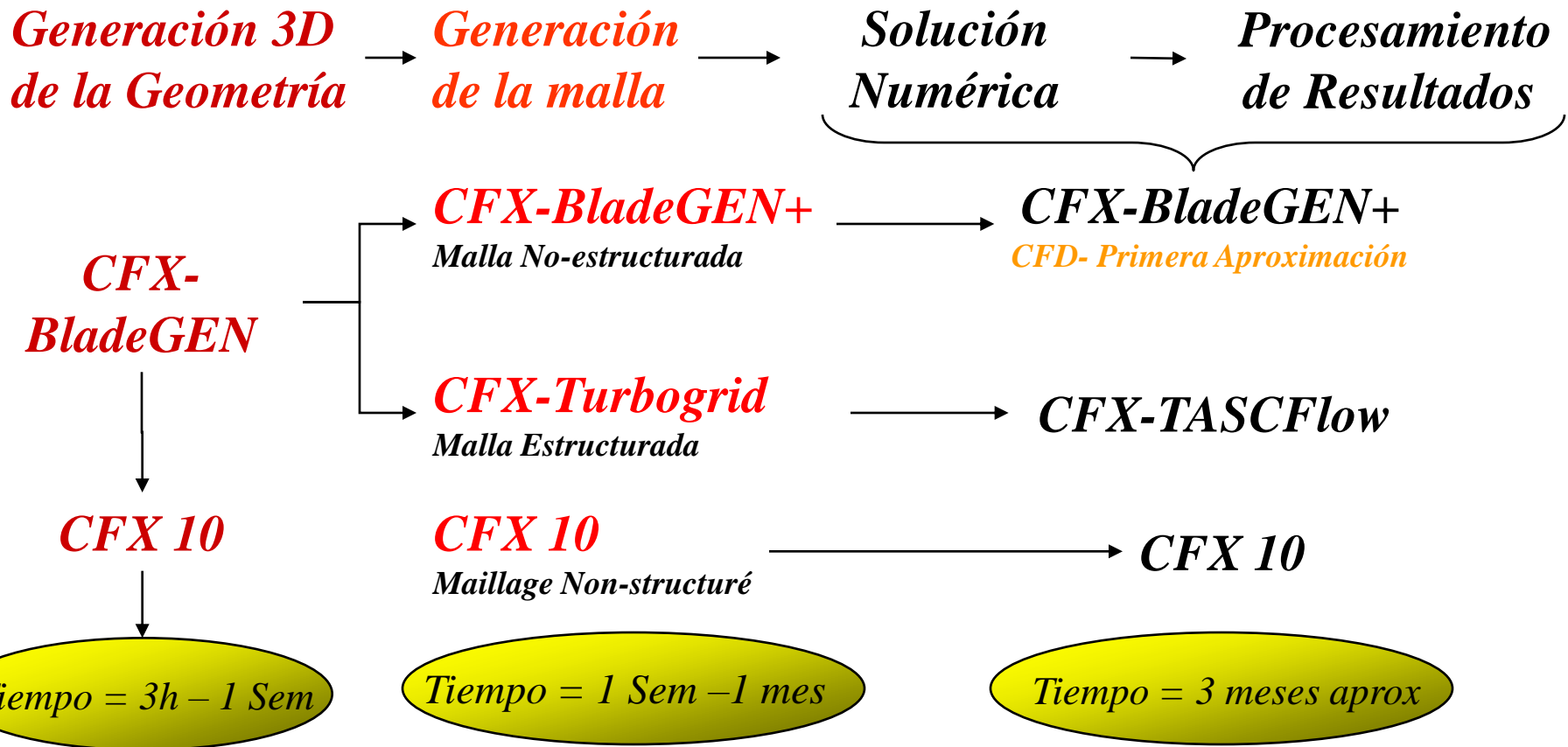
Estado $\frac{p}{\rho} = r T$

Resolvemos las ecuaciones de Conservación apoyados en métodos numéricos y modelos matemáticos de fenómenos complejos como la turbulencia

MFC « Laboratorios Virtuales »

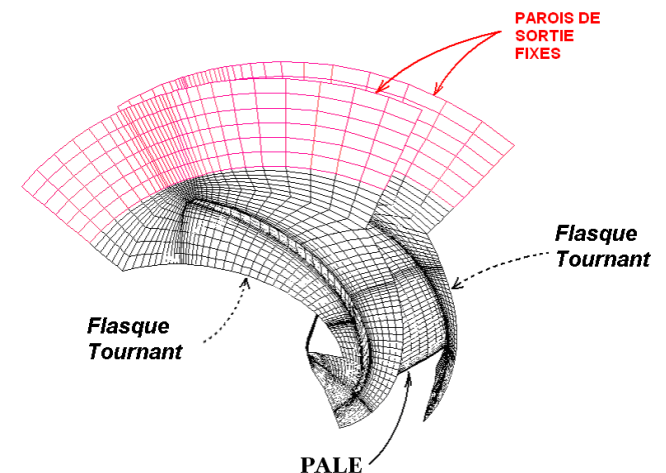
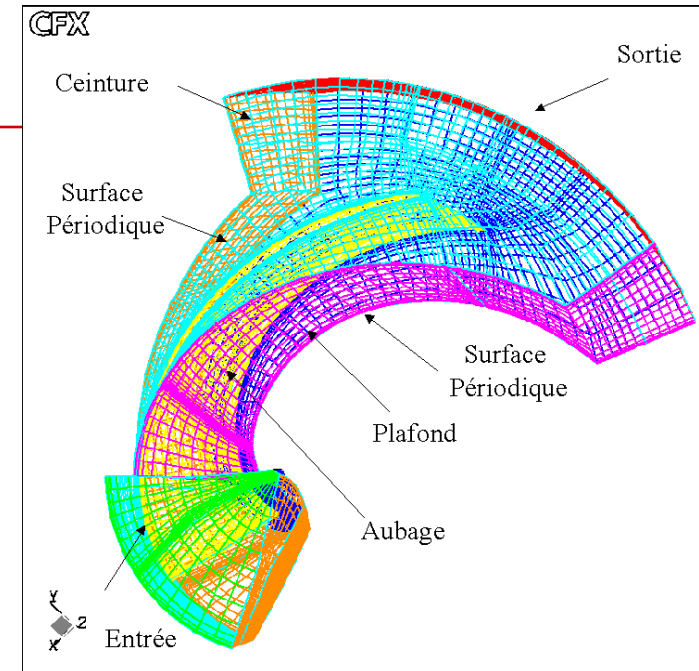


Las diferentes etapas de la CFD ...

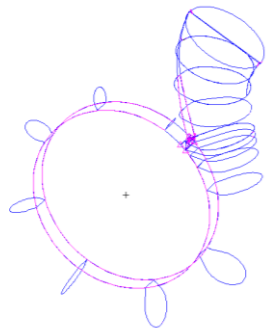


MFC ... Fronteras y Condiciones de Cálculo

Característica	CFX- BladeGEN+	CFX-10
Dominio	1 pasaje o canal de álabe (Condición de periodicidad)	1 pasaje o canal de álabe (Condición de periodicidad)
Malla	No-Estructurada 51.552 Nodos	Estructurada 49.824 Nodos
Cond. de Borde Entrada	Presión Total = 101325,0 [Pa]	Presión Total = 101325,0 [Pa]
Cond. de Borde Salida	Flujo Másico = Variable [kg/s]	Flujo Másico = Variable [kg/s]
Modelo de Turbulencia	Zéro équation	$k - \varepsilon / k - \omega / SST$
Esquema Numérico de Resolución	Second ordre	Second ordre
Residuo Medio (RSM)	10^{-4}	10^{-4}



Estudio de la bomba Completa Rotor-Voluta



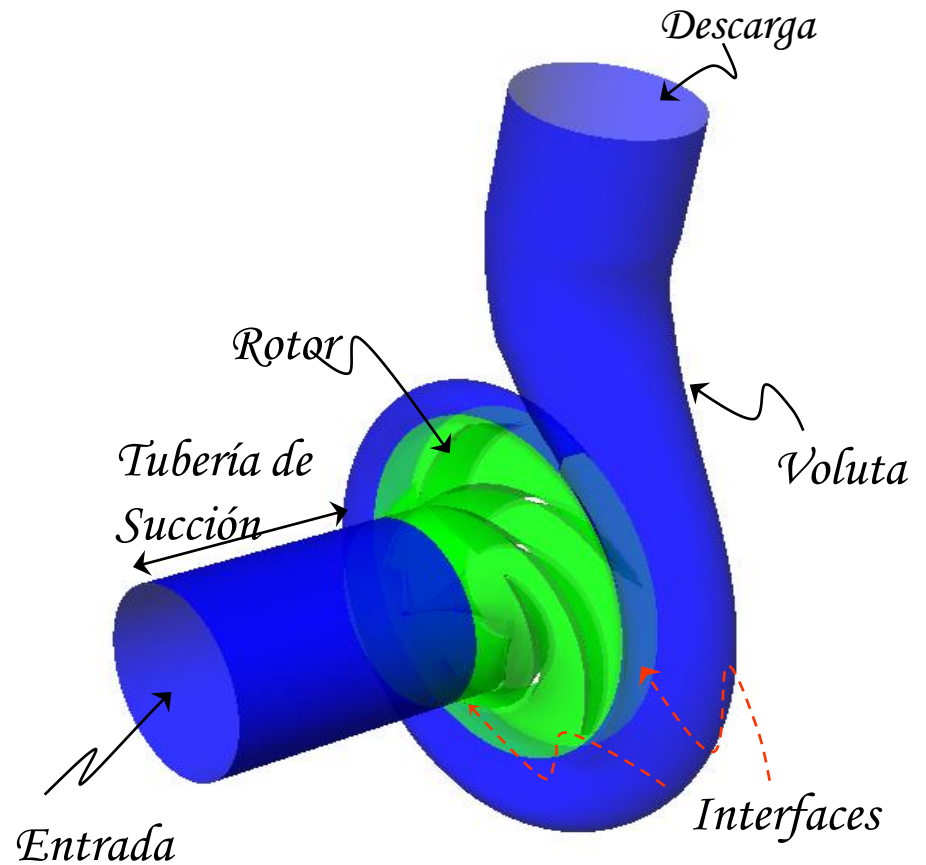
*Secciones
Transversales*



Superficie

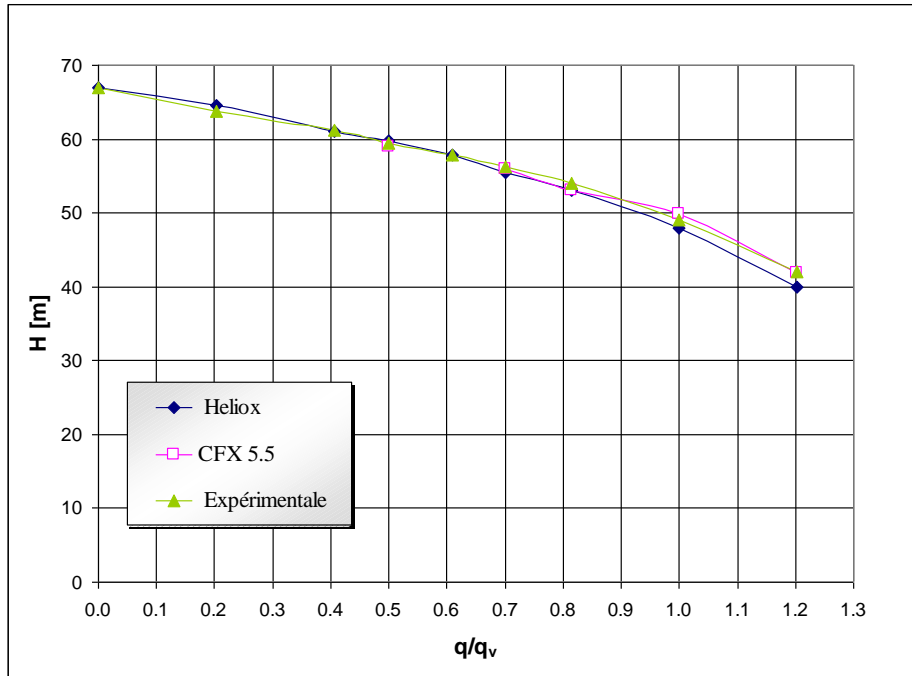


*Sólido y
Malla*



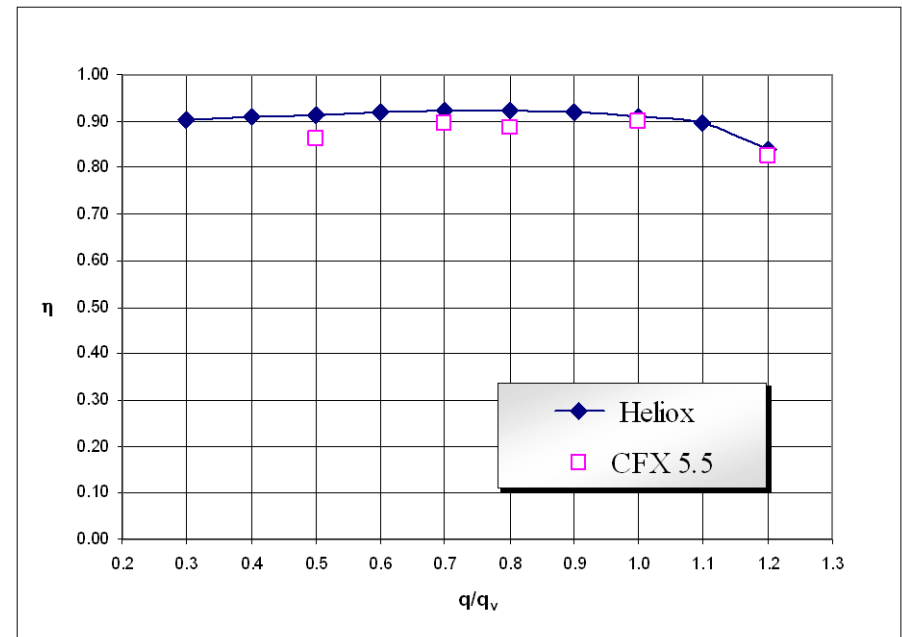
Dominio de Cálculo

Curvas Características

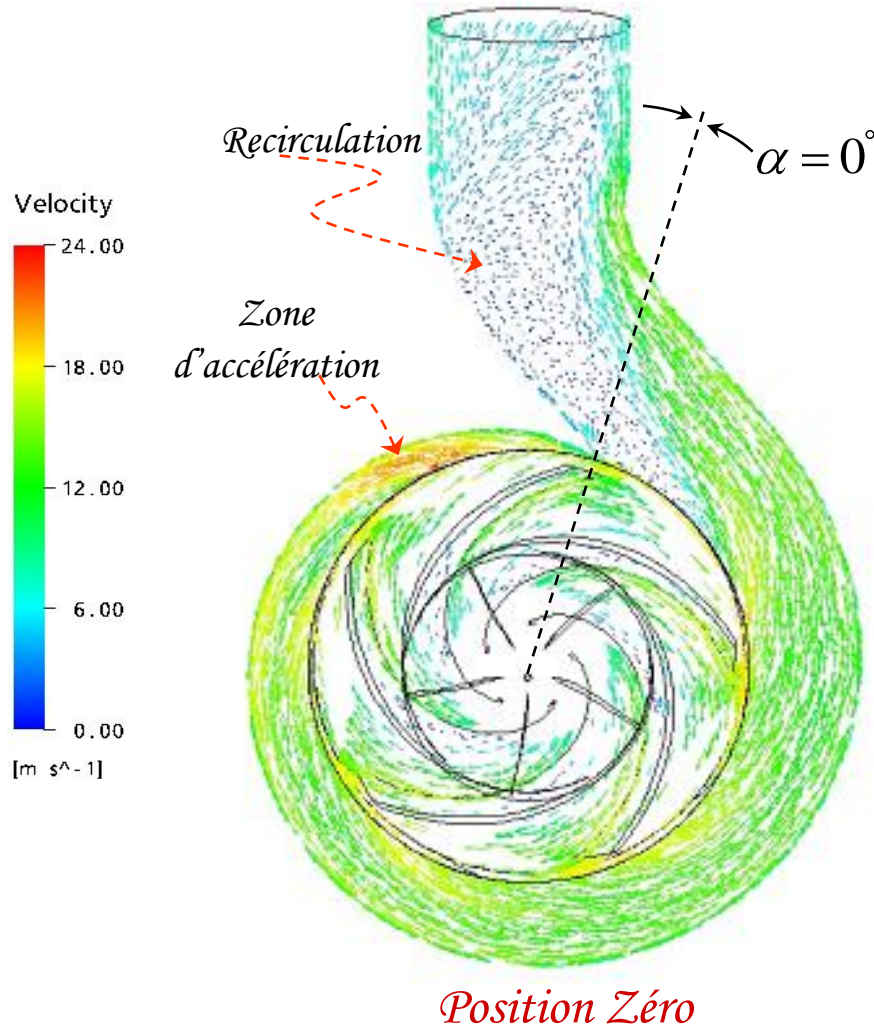


Altura vs. Caudal

Rendimiento hidráulico vs. Caudal

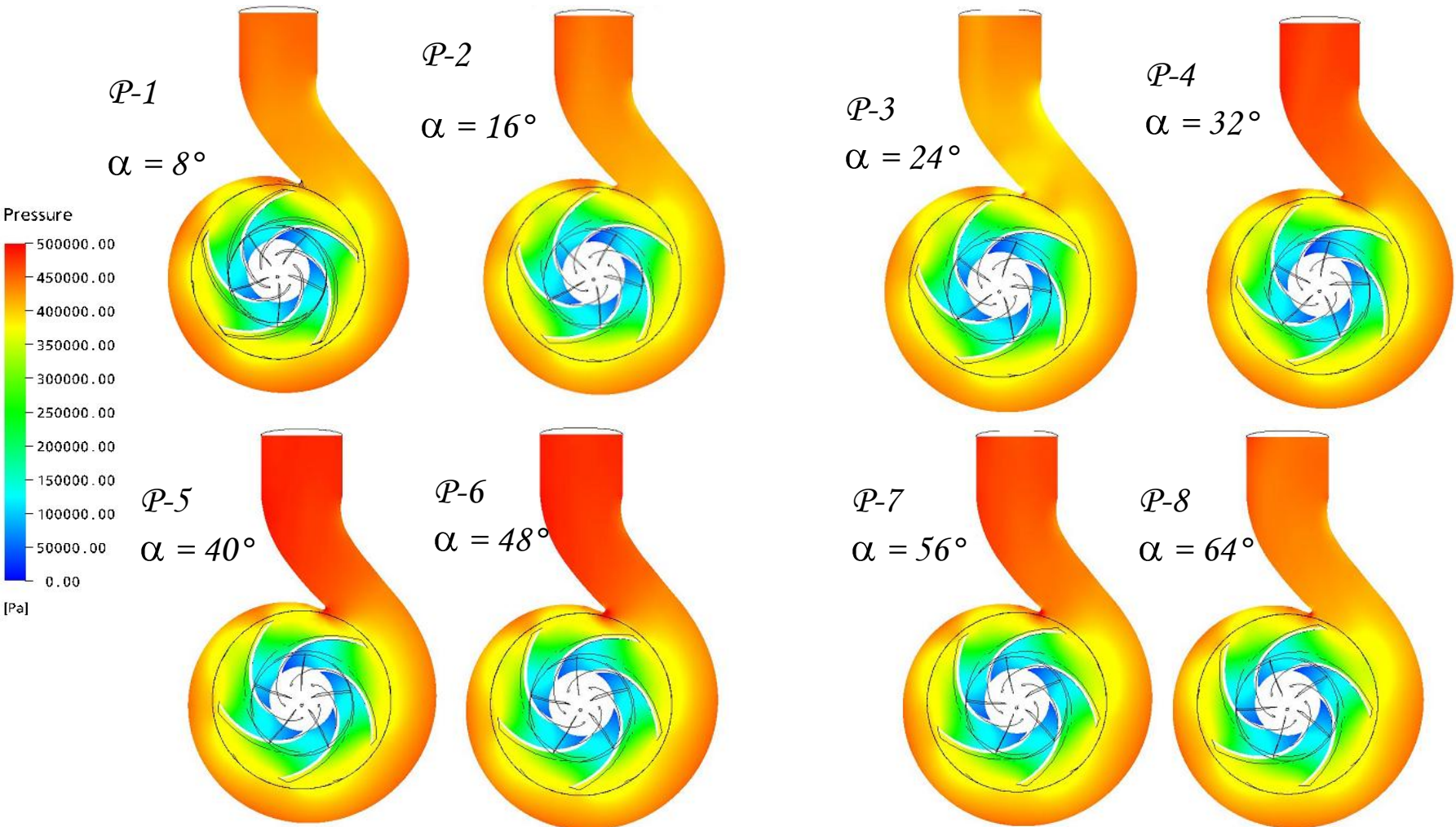


Plano de estudio. Bomba NS32

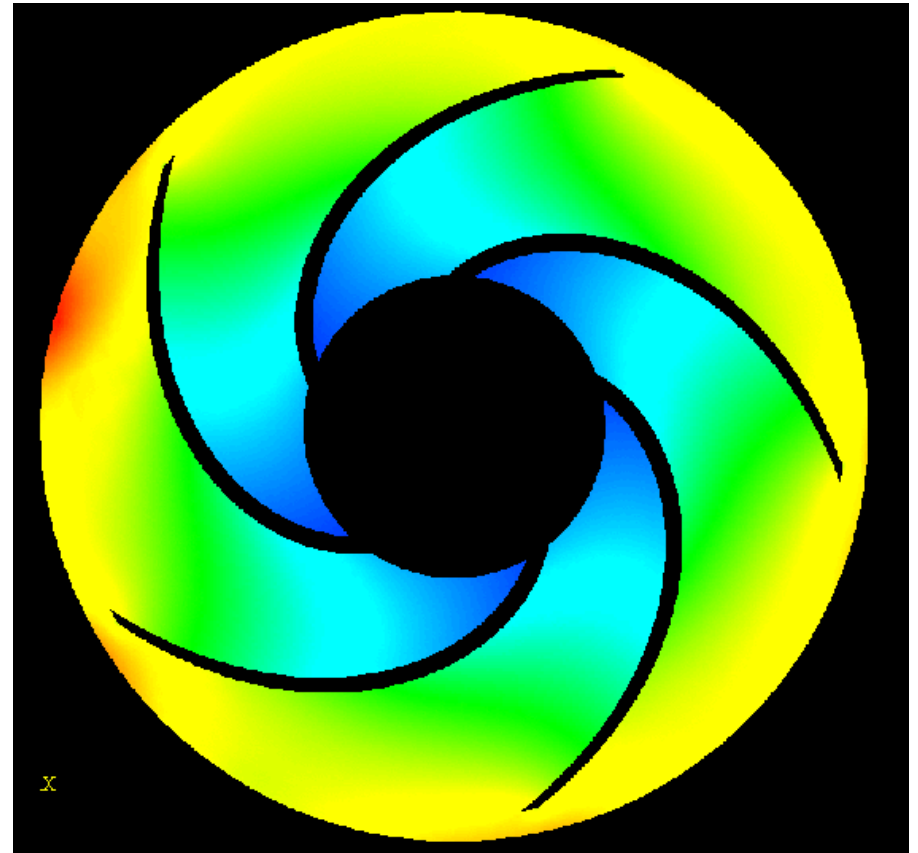
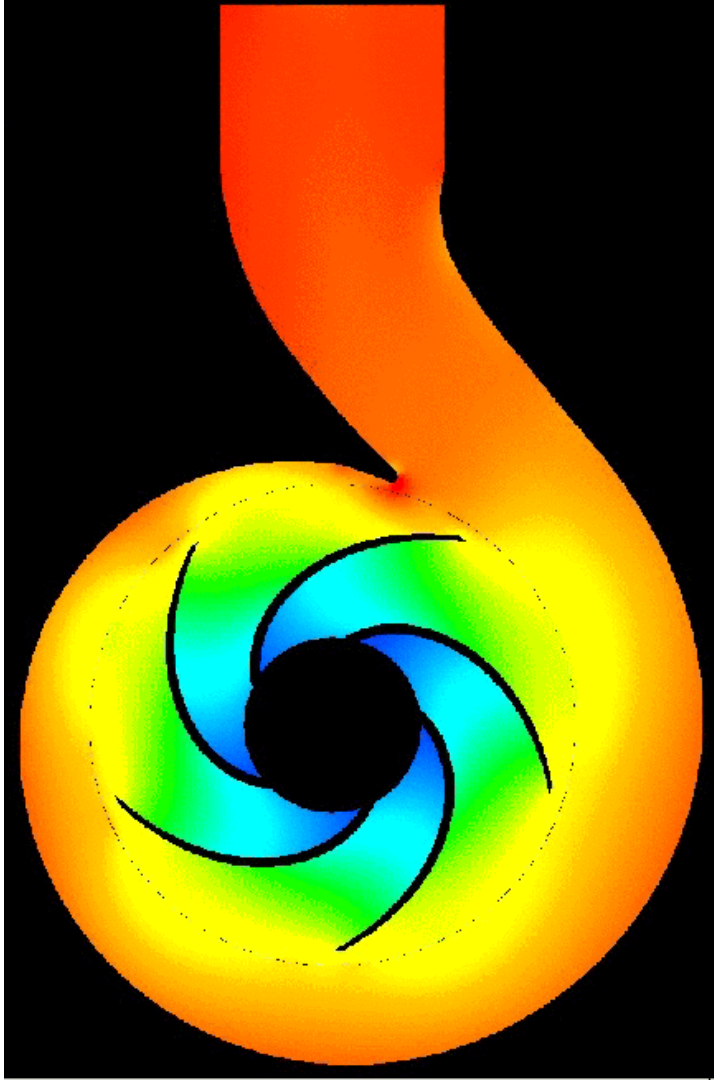


*Campo de
Velocidades
 $q_v/q_n=1.0$*

Campo de Presión $q_v/q_n=1,0$

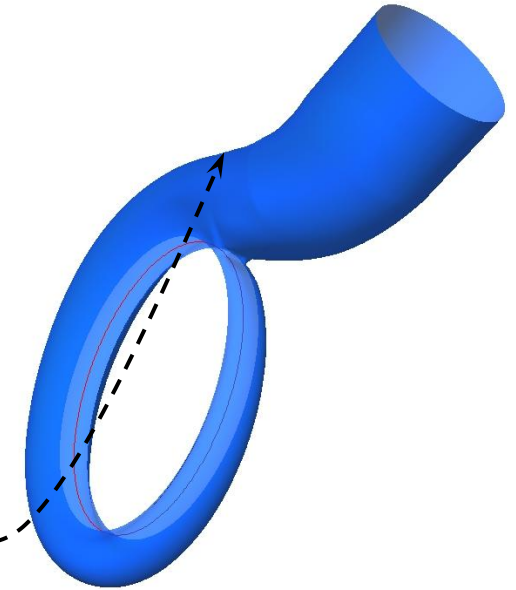
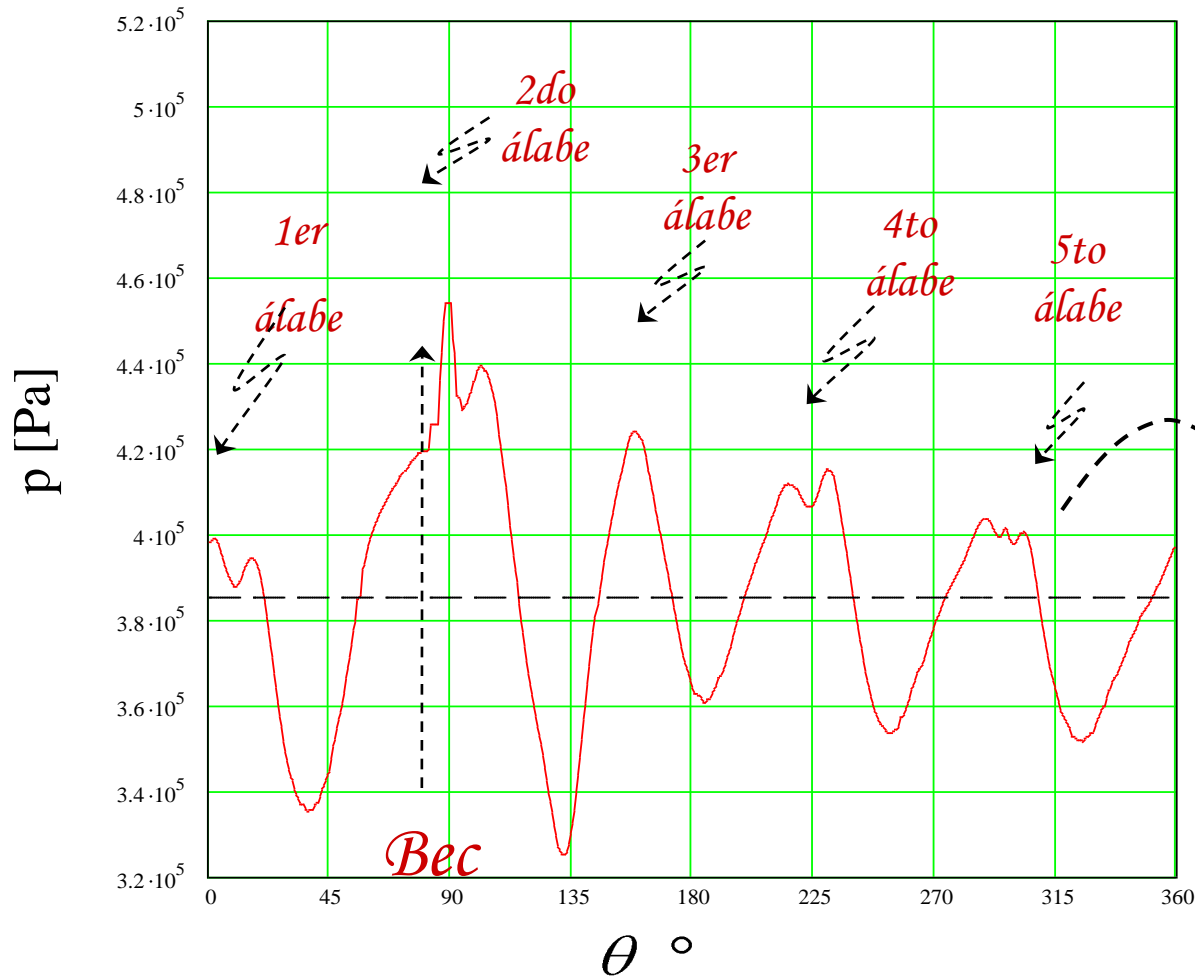


Campo de Presión $q_v/q_n=1,0$



Fluctuaciones de Presión en la interface Rotor-Voluta

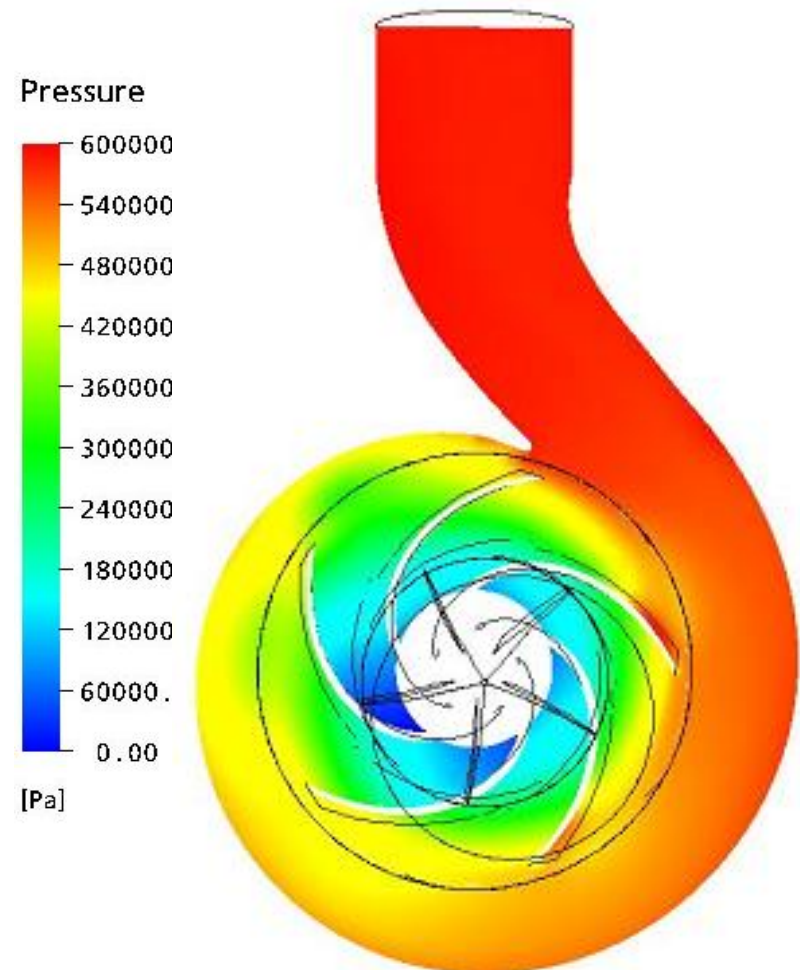
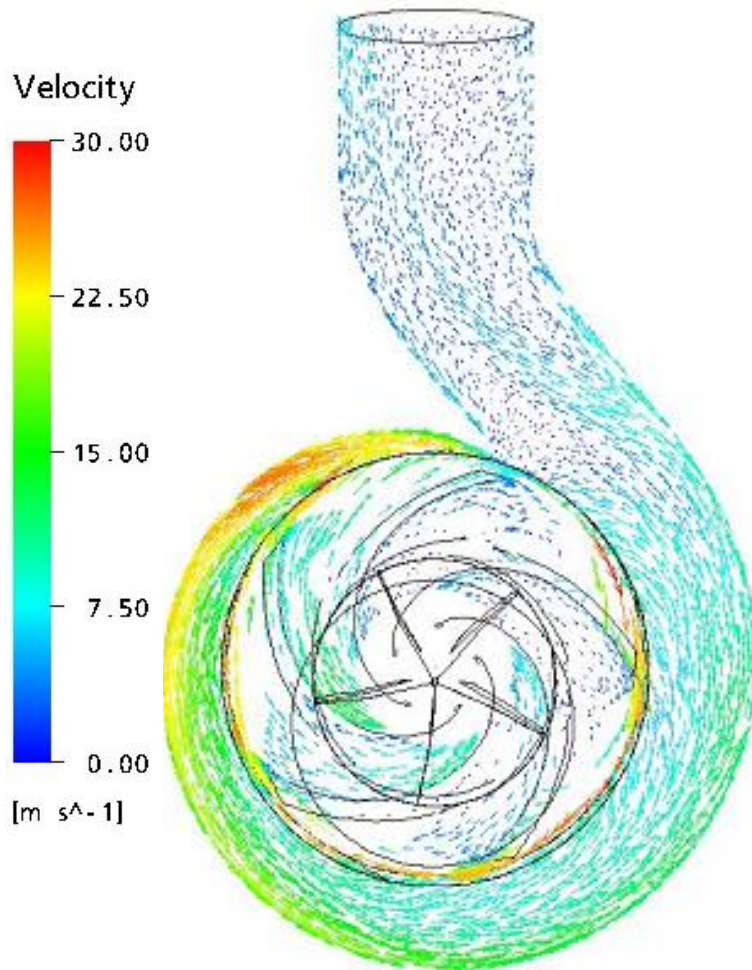
$$q_v/q_n = 1,0$$



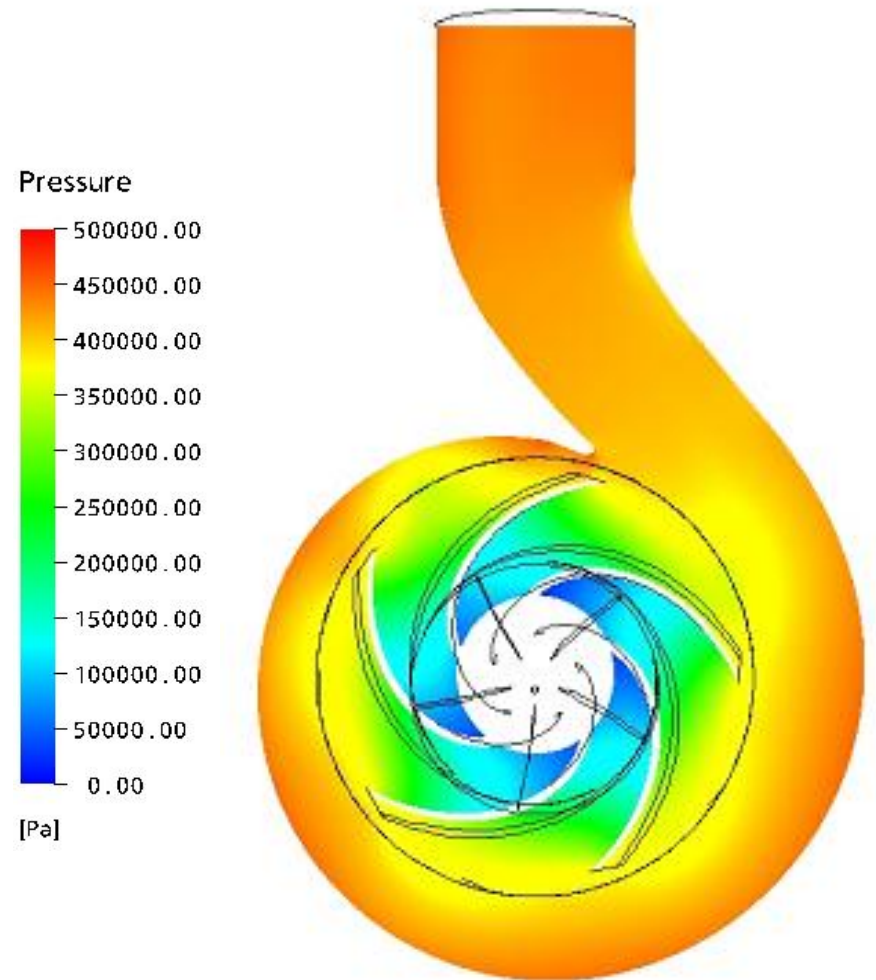
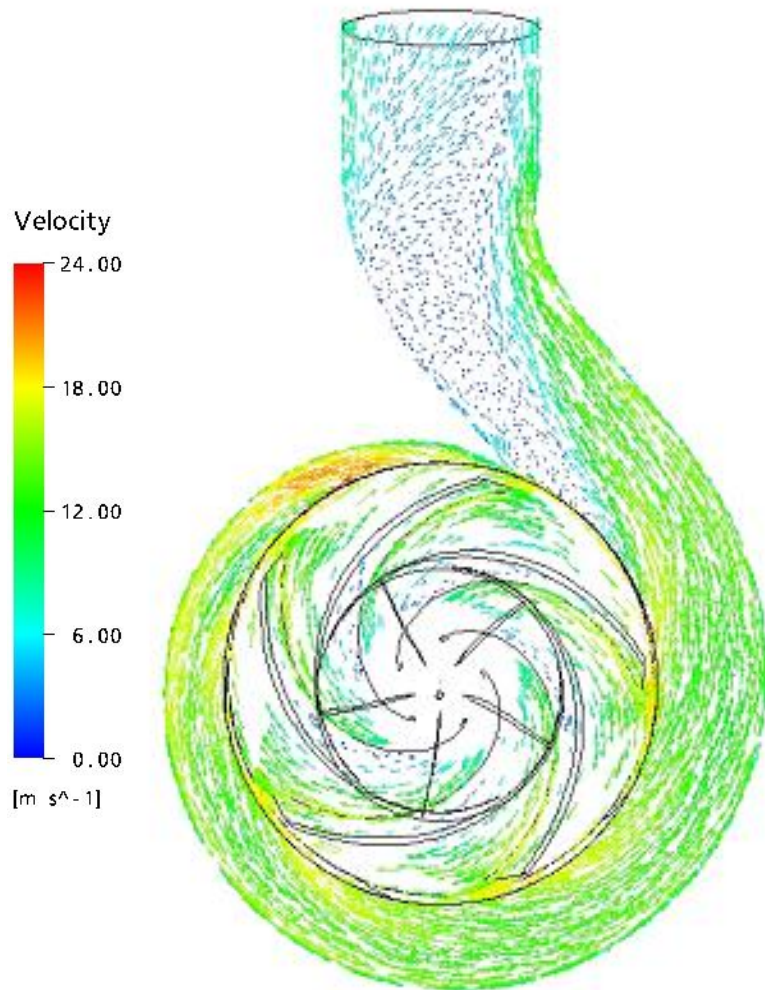
Position 1
 $\alpha = 0^\circ$

Resultados para caudales parciales

$q_v/q_n=0,5$

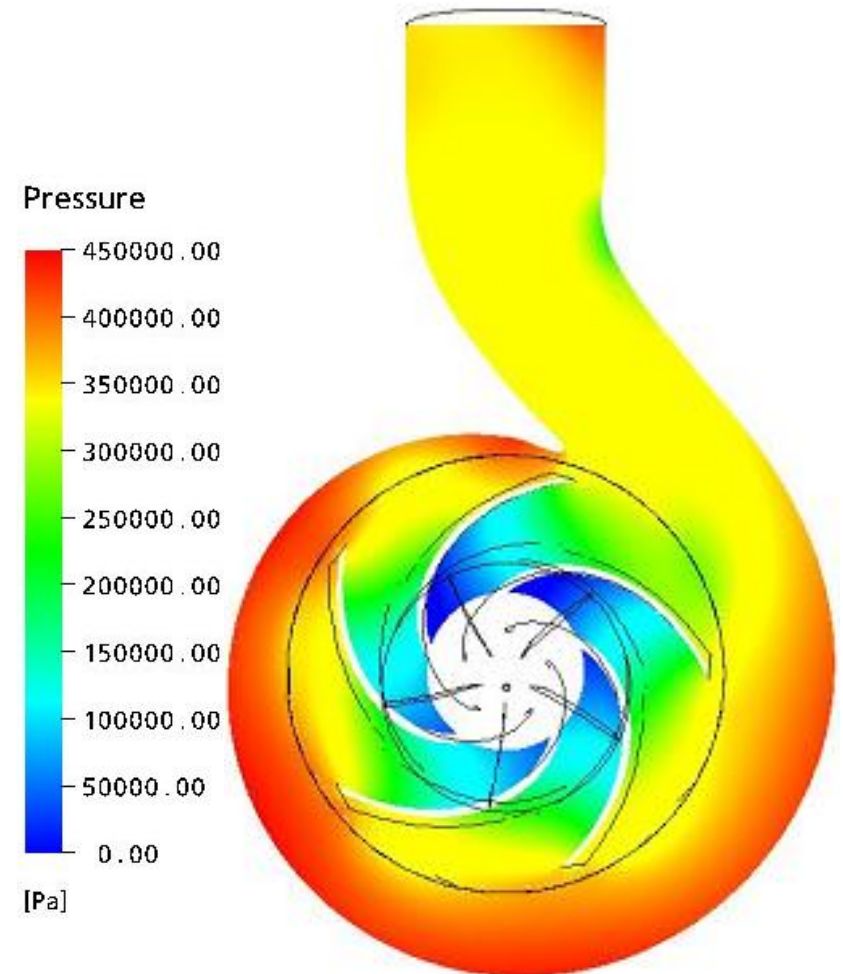
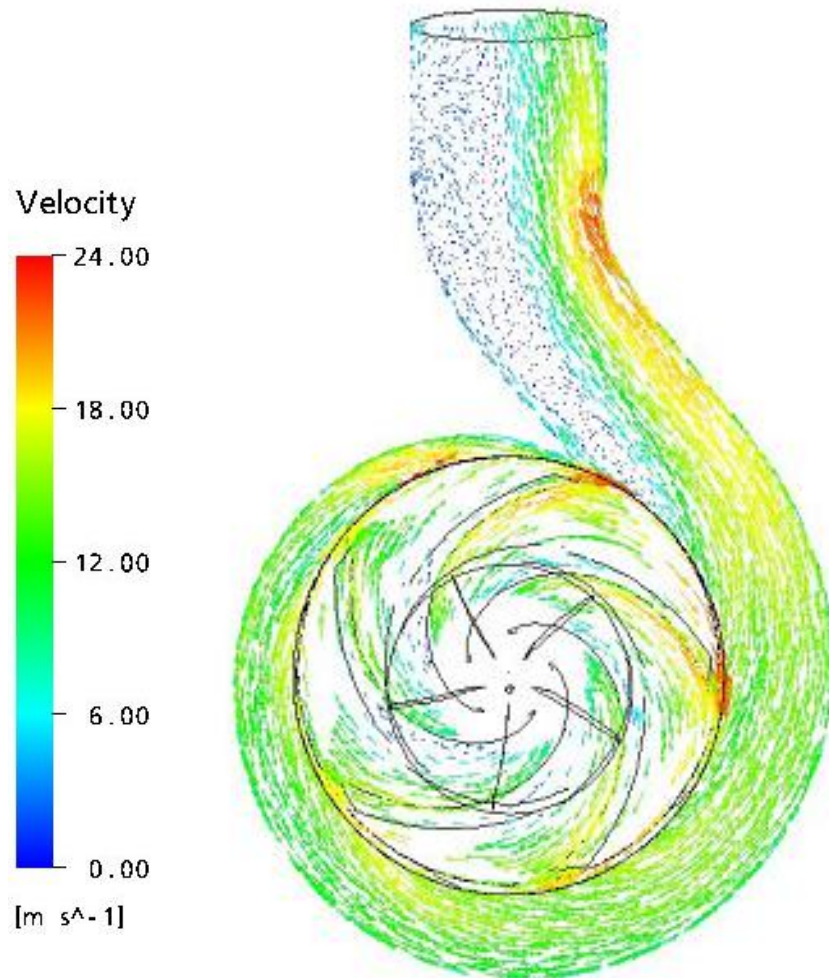


Caudal Nominal $q_v/q_n=1,0$



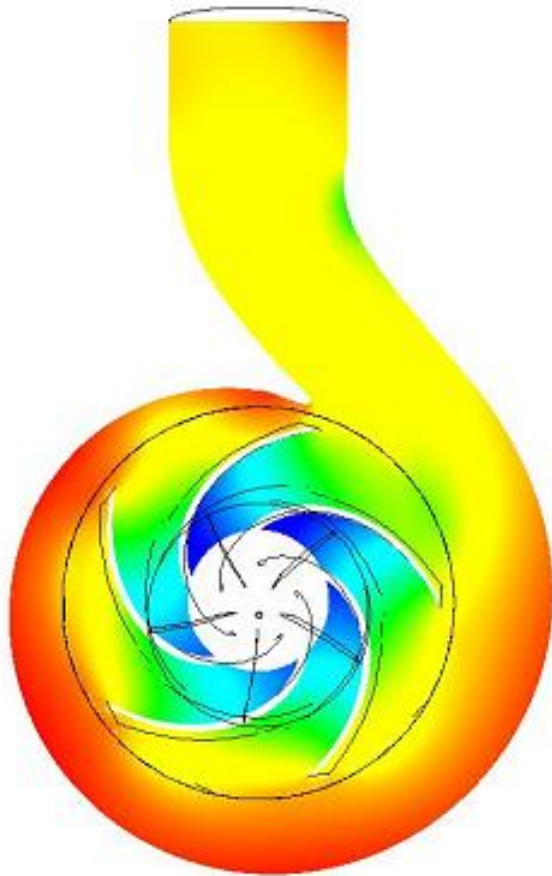
Caudales superiores al nominal

$$q_v/q_n = 1,2$$

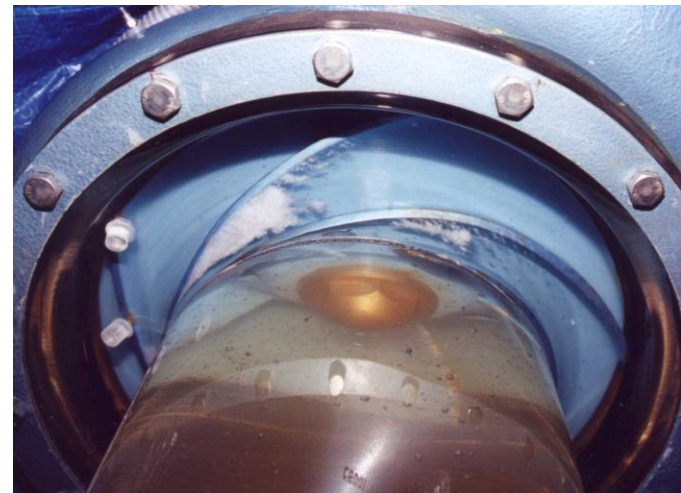


Podemos observar zonas propensas a la cavitación

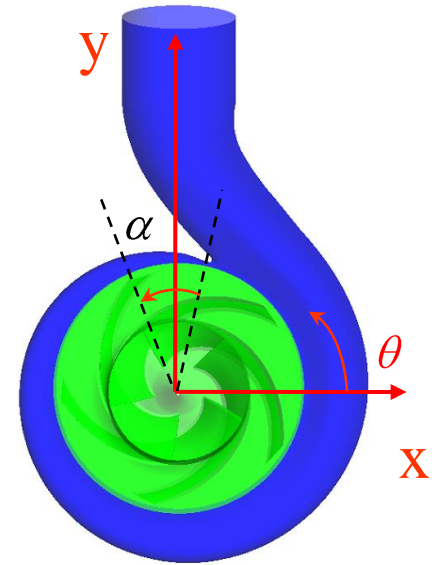
$$q_v/q_n=1,2$$



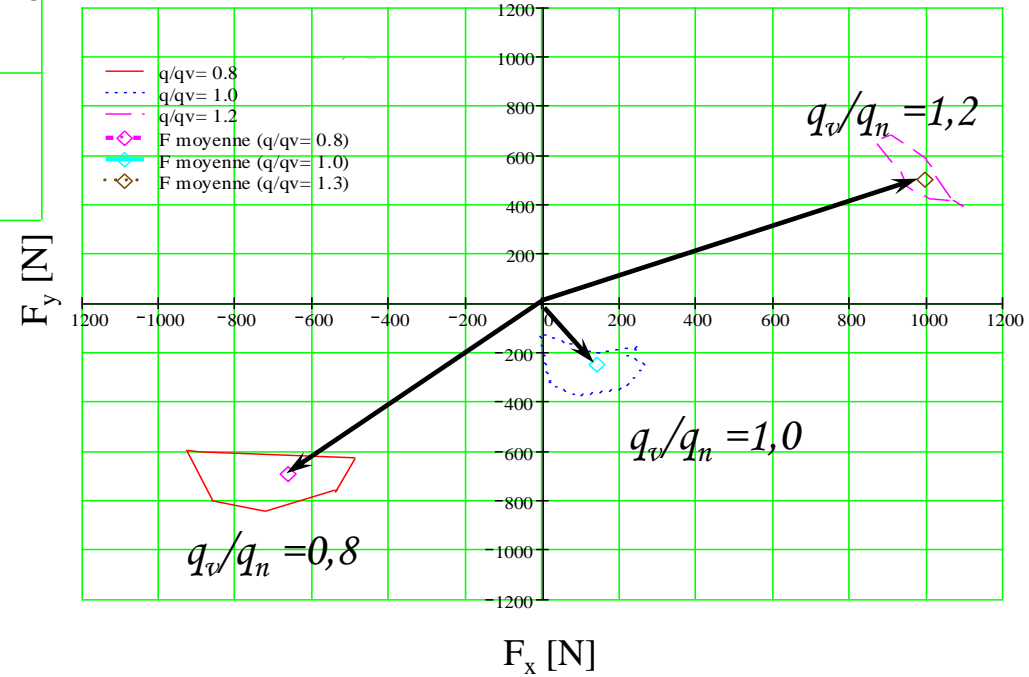
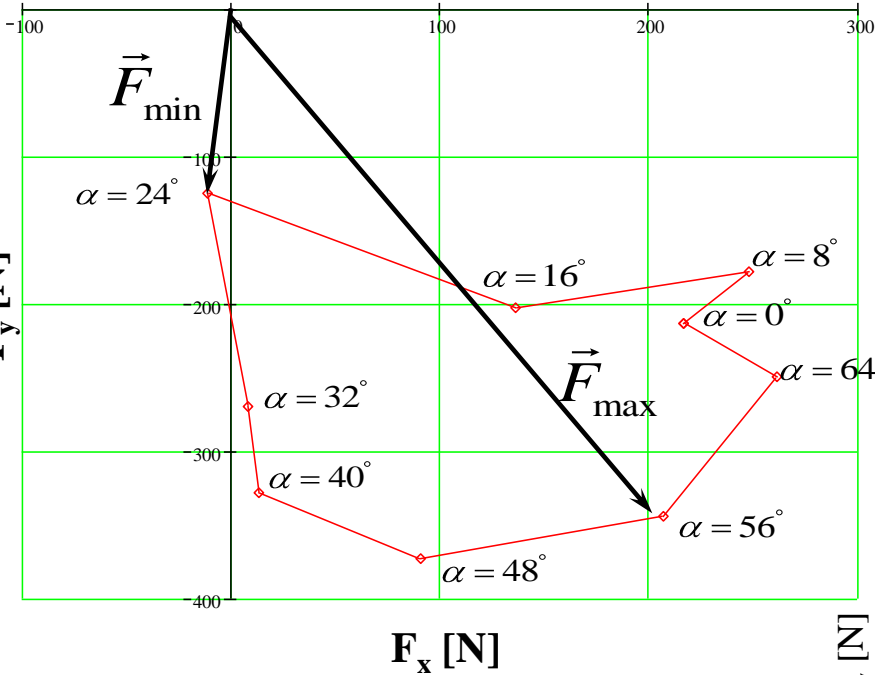
Cavitation pompe NS32



Fluctuaciones del Empuje



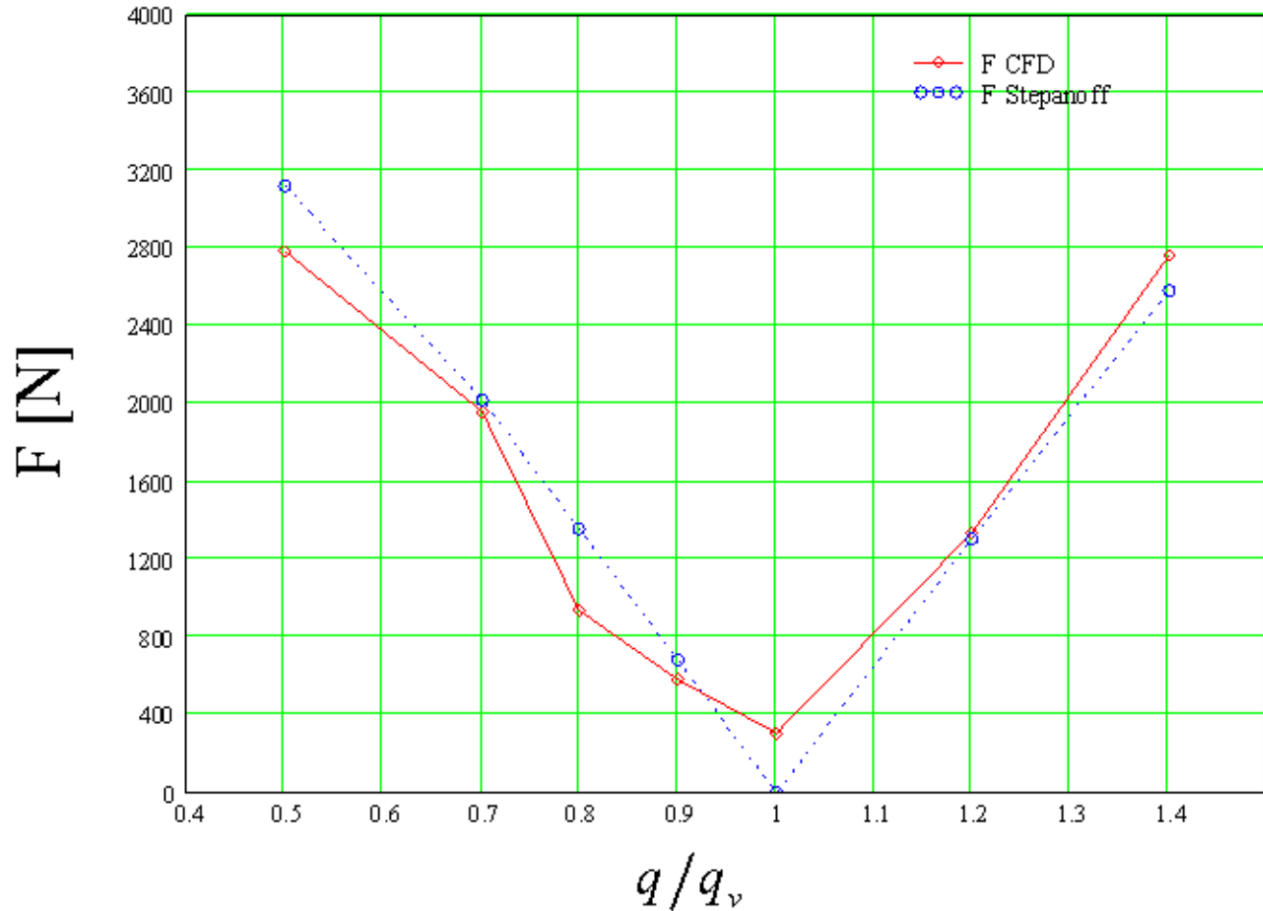
$q_v/q_n = 1,0$



Diferentes Caudales

El Empuje Radial en función del caudal ...

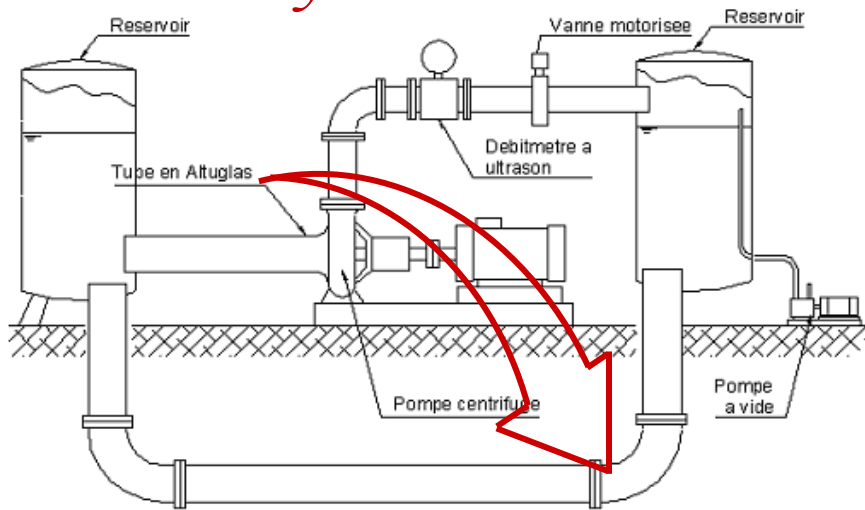
*Comparación
con
correlaciones
experimentales*



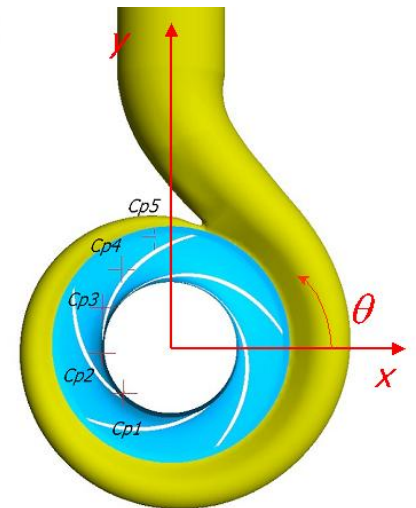
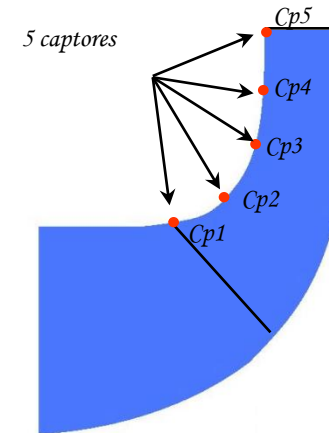
Comparación con correlación experimental de Stepanoff

Validación experimental

Banco de ensayos ...

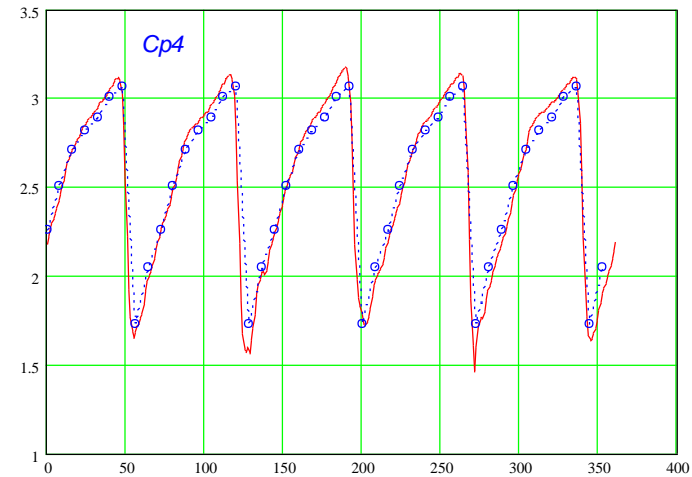
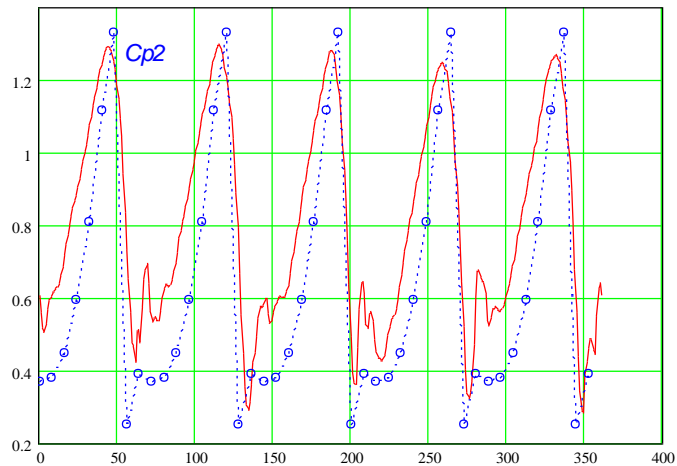
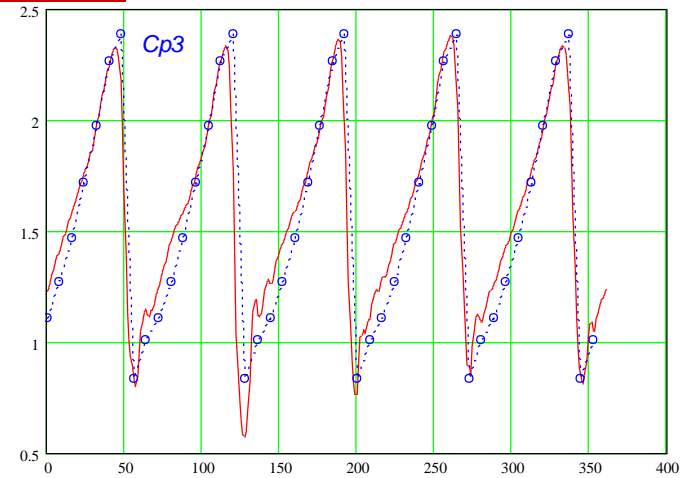
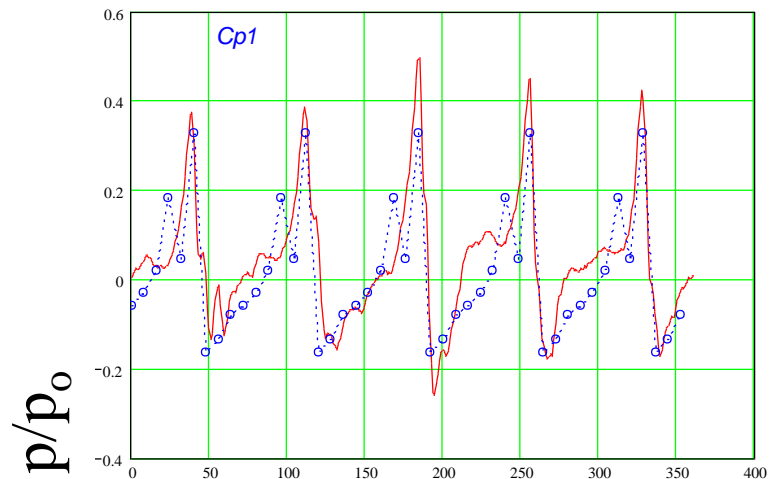


Colocación de Captores de Presión



Fluctuaciones de presión sobre el rotor

$q_v/q_n = 1,0$



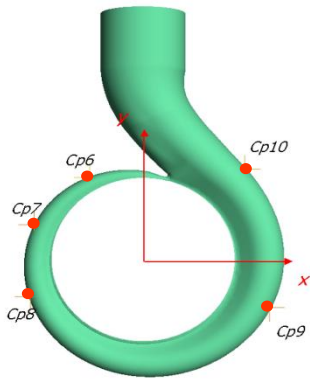
— Expériméntale
○ Simulation

θ °

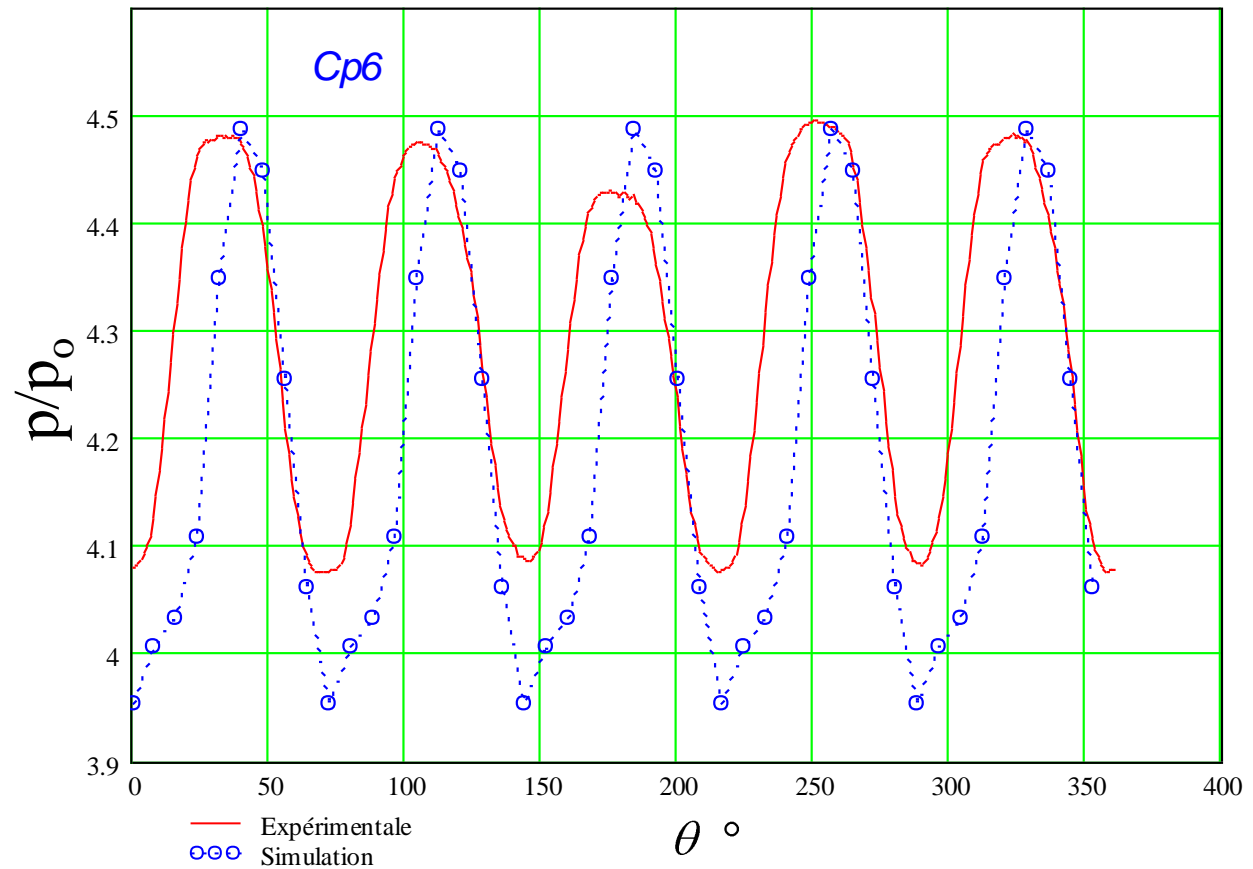
θ °

Fluctuaciones de presión sobre la voluta

$$q_v/q_n = 1,0$$



Capteur	[]
Cp6	120,0
Cp7	160,0
Cp8	200,0
Cp9	337,0
Cp10	45,0



Para minimizar el empuje radial

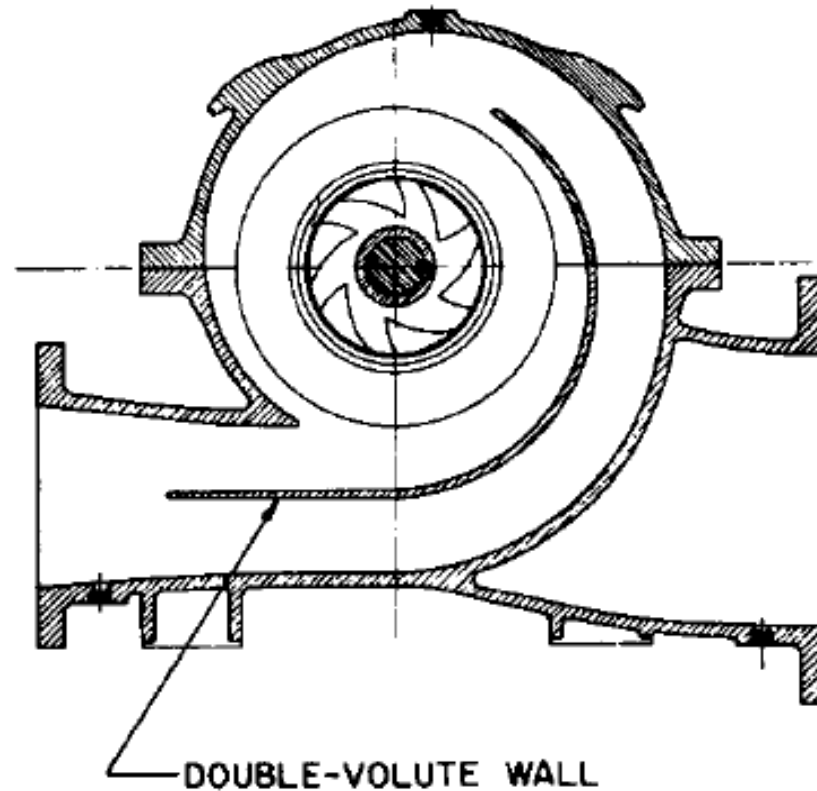
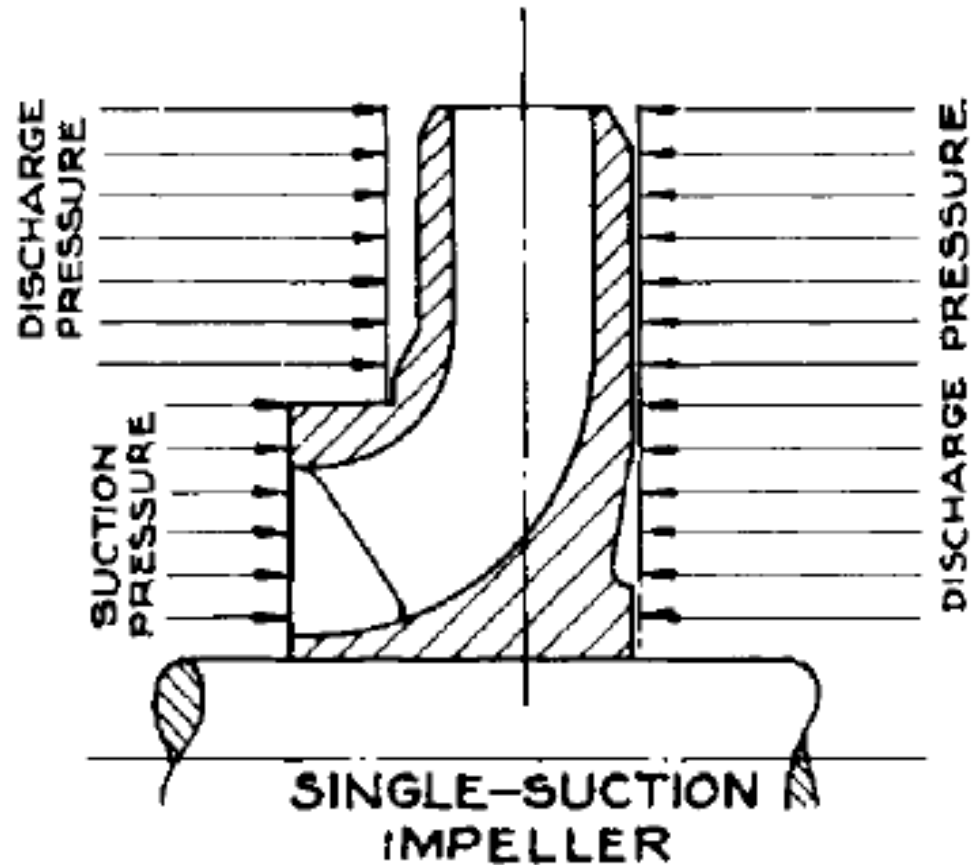


FIGURE 7 Transverse view of a double-volute casing pump.

Empuje Axial

Empuje Axial

Esquema simplificado:



Efecto de la presión de Succión en el Empuje Axial

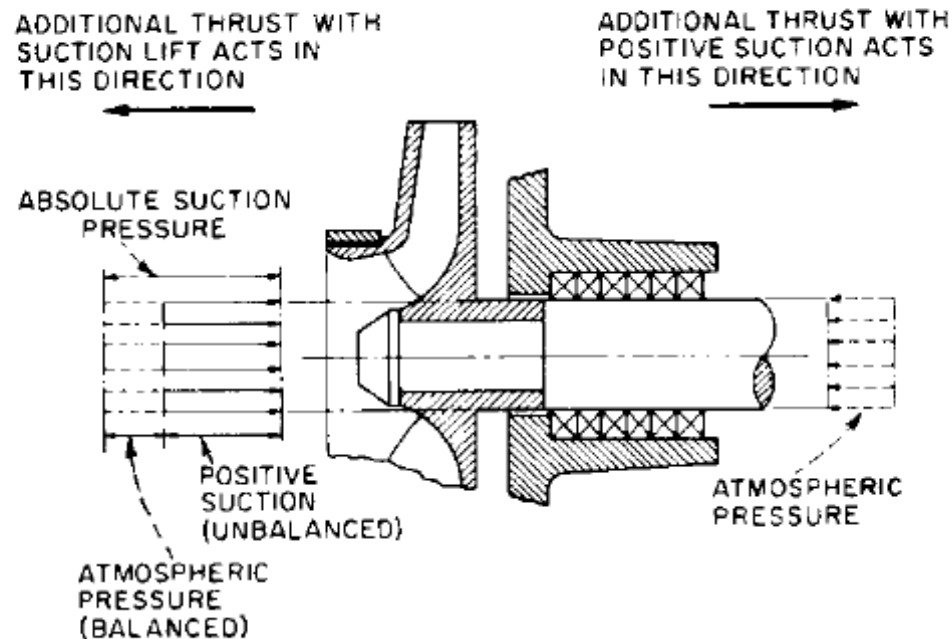


FIGURE 57 An axial thrust problem with a single-suction, overhung impeller and a single stuffing box or seal chamber

Distribución de Presión

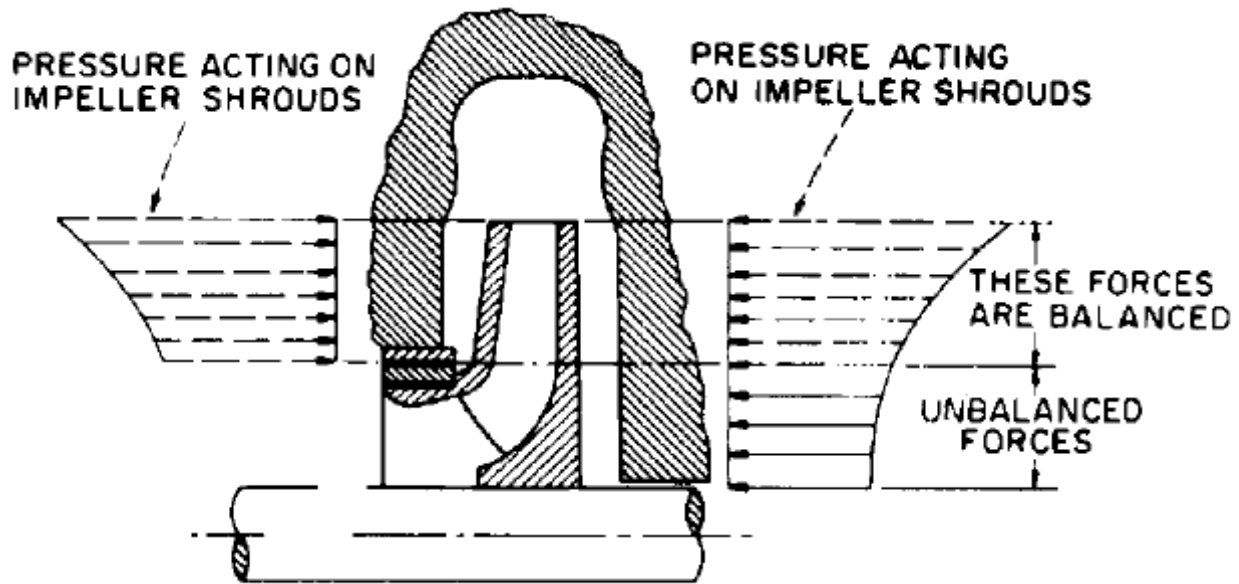
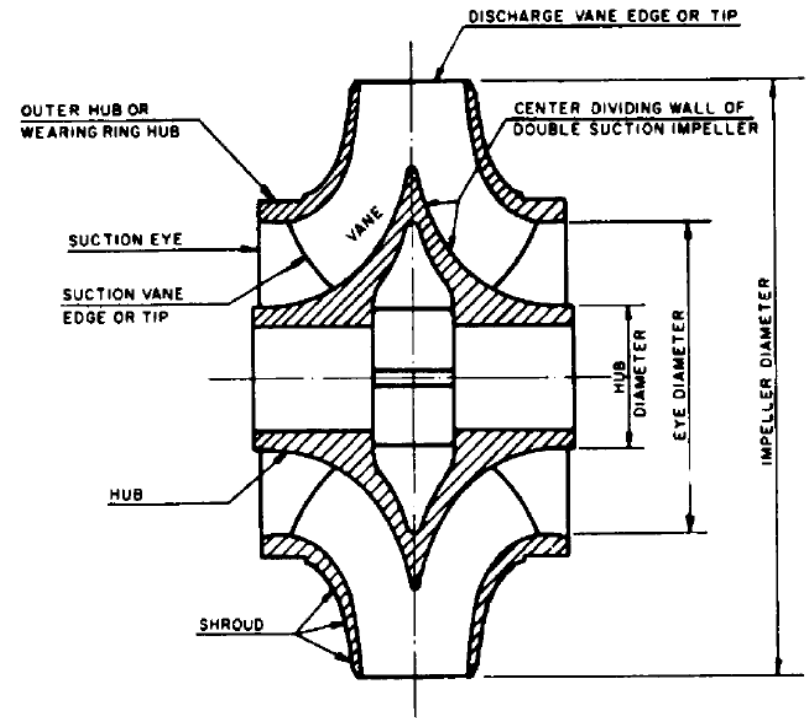
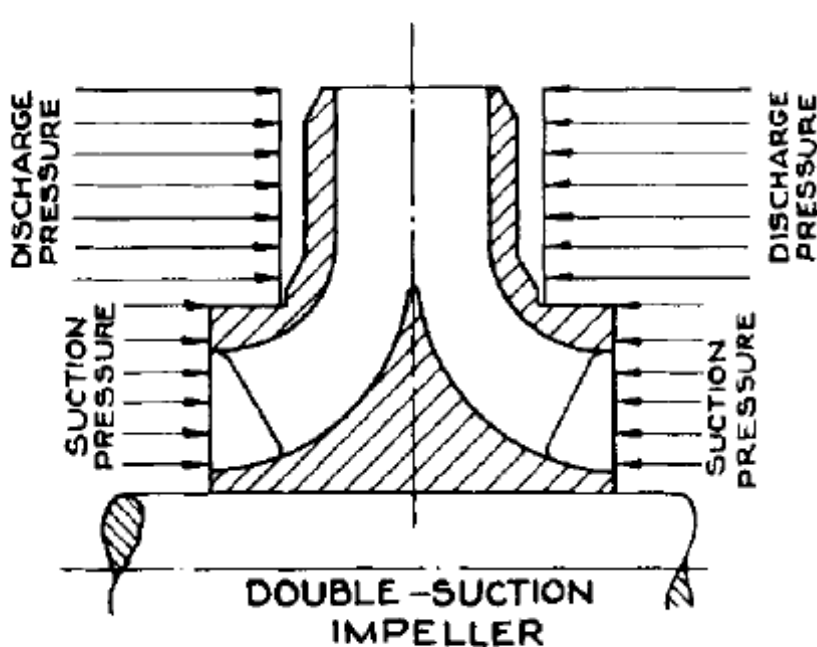


FIGURE 54 Pressure distribution on the front and back shrouds of the single-suction impeller with a shaft through the impeller eye

Métodos de Control del Empuje Axial. Rotor de Doble Succión



Bombas multietapas con rotores superpuestos

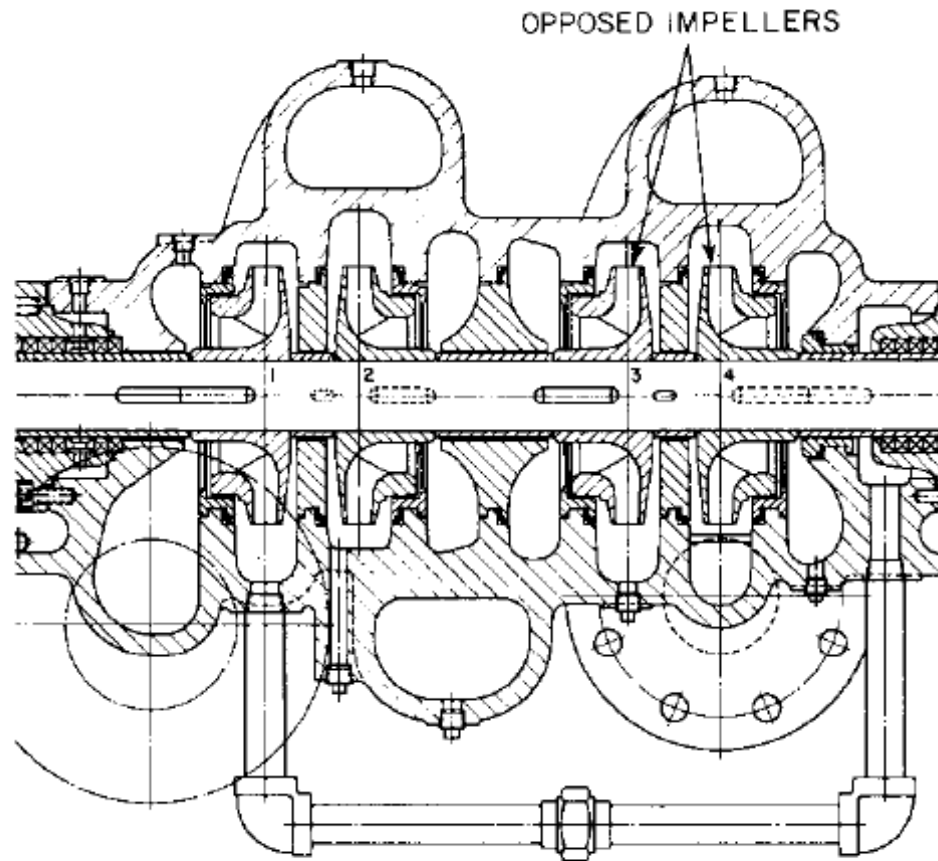


FIGURE 60 A four-stage pump with opposed impellers (Flowserve Corporation)

Métodos de Control del Empuje Axial. Álabes en el Cubo

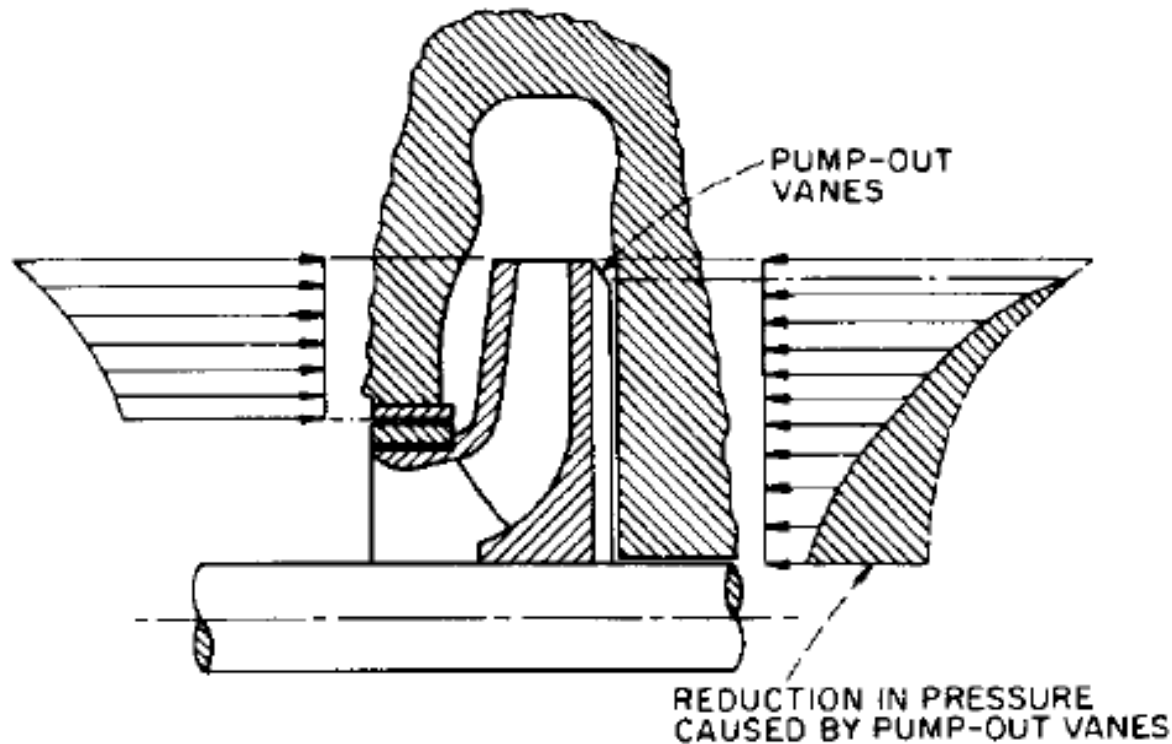


FIGURE 56 Pump-out vanes used in a single-suction impeller to reduce axial thrust

Métodos de Control del Empuje Axial. Agujeros en el Cubo

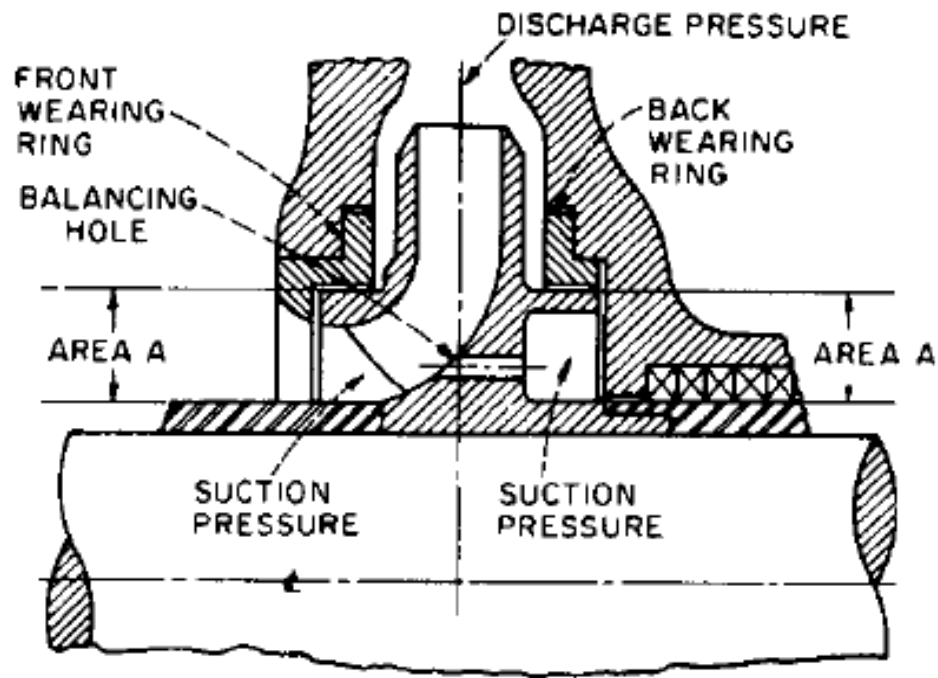


FIGURE 55 Balancing the axial thrust of a single-suction impeller by means of wearing rings on the back side and balancing holes

Métodos de Control del Empuje Axial. Cámara de Balanceo

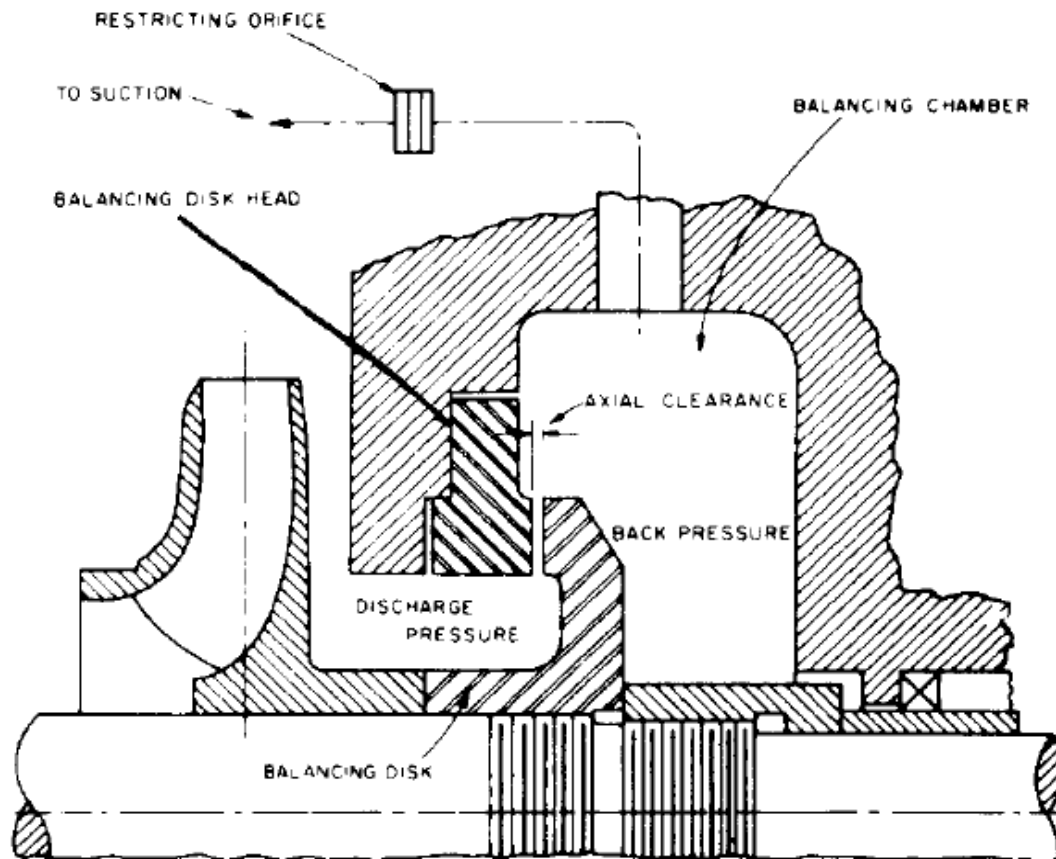


FIGURE 62 A simple balancing disk

Métodos de Control del Empuje Axial. Tambor de Balanceo

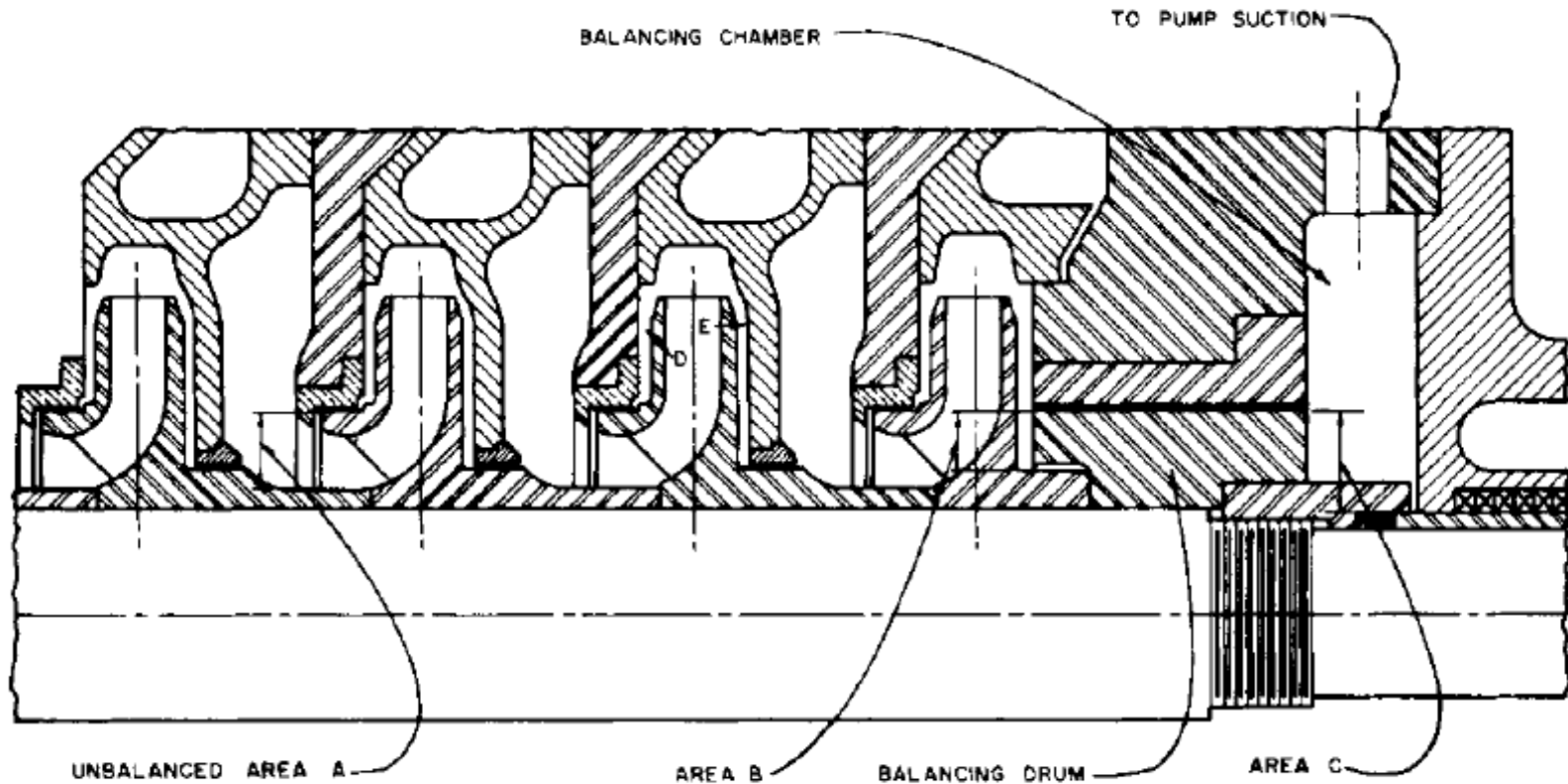


FIGURE 61 Balancing drum

Métodos de Control del Empuje Axial. Tambor de Balanceo

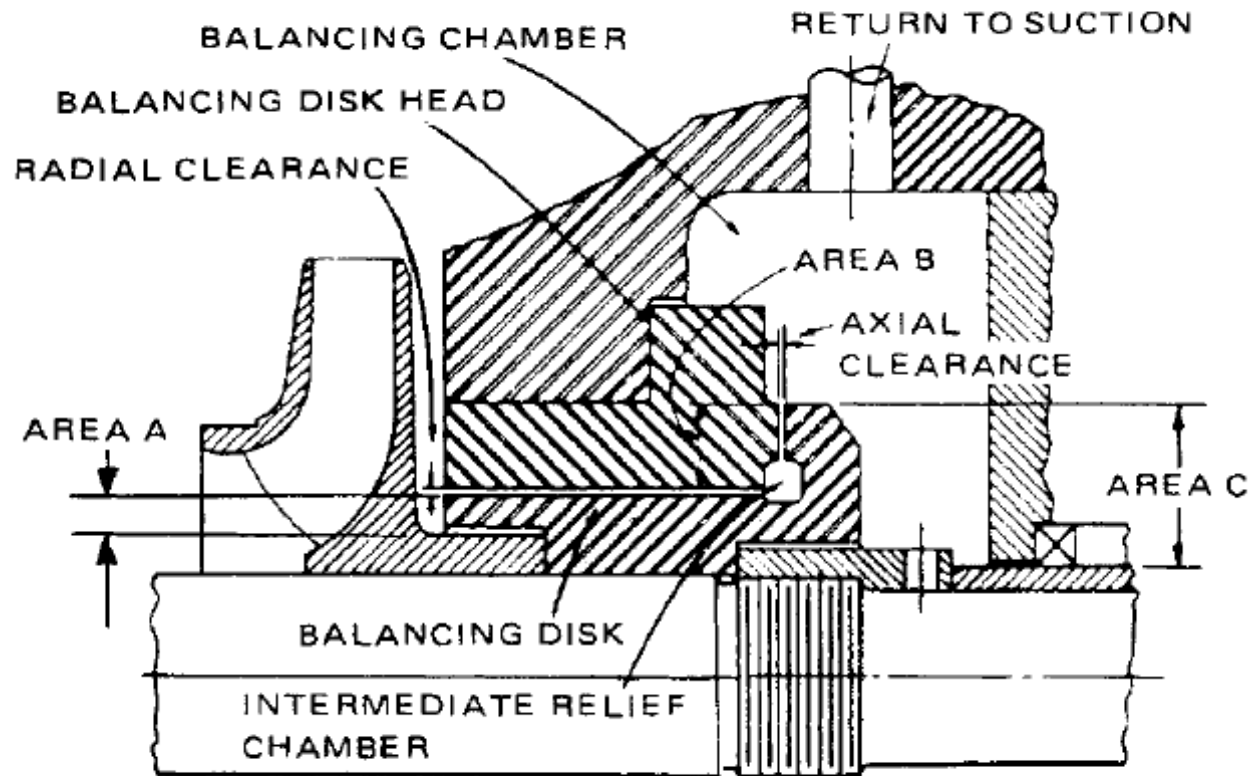


FIGURE 63 A combination balancing disk and drum