

<p>OXY CÁLCULO NEUMÁTICO DE LA RED DE SUMINISTRO DE AIRE - MICROBURBUJAS WEMCO</p>	<p>Nº OXY OXY-WEM-P-INF-003</p>
	<p>17 ENERO 2017</p>
	<p>ELABORÓ: H.GASCA</p>
	<p>REV. 1</p>

Nº OXY
OXY-WEM-P-INF-003

ELABORÓ:
H.GASCA

CÁLCULO NEUMÁTICO PARA TUBERÍA DE ALIMENTACIÓN DE FILTROS SISTEMA DE MICROBURBUJAS EN CELDAS WEMCO

TABLA DE CONTENIDO

1. INTRODUCCIÓN	3
2. OBJETIVO	3
3. RESULTADOS	3
3.1. CONDICIONES DEL ANÁLISIS:	3
3.2. TOPOLOGÍA DE LA RED:	4
3.2. CAUDAL Y PRESIÓN	5
4. DESCRIPCIÓN DE LOS MODELOS NEUMÁTICOS UTILIZADOS PARA EL CÁLCULO	5
5. DOCUMENTOS DE REFERENCIA	5
6. UNIDADES	6
7. GLOSARIO	6
8. ANEXOS	7

1. INTRODUCCIÓN

Como parte del proyecto de OXY para hacer factible el reemplazo del sistema de flotación producida por los rotores originales por operación con micro burbujas se requiere realizar el cálculo del Manifold de distribución de aire.

2. OBJETIVO

Se deben plantear opciones a lo instalado en campo para obtener una distribución más uniforme de los caudales a la entrada de los 84 filtros de producción de burbujas. Adicionalmente se requiere realizar un cálculo análogo para una configuración de 60 filtros ubicados en las tres primeras cámaras de la celda de flotación.

En la figura No. 1 se muestra la distribución actual de las tuberías del Manifold de alimentación.

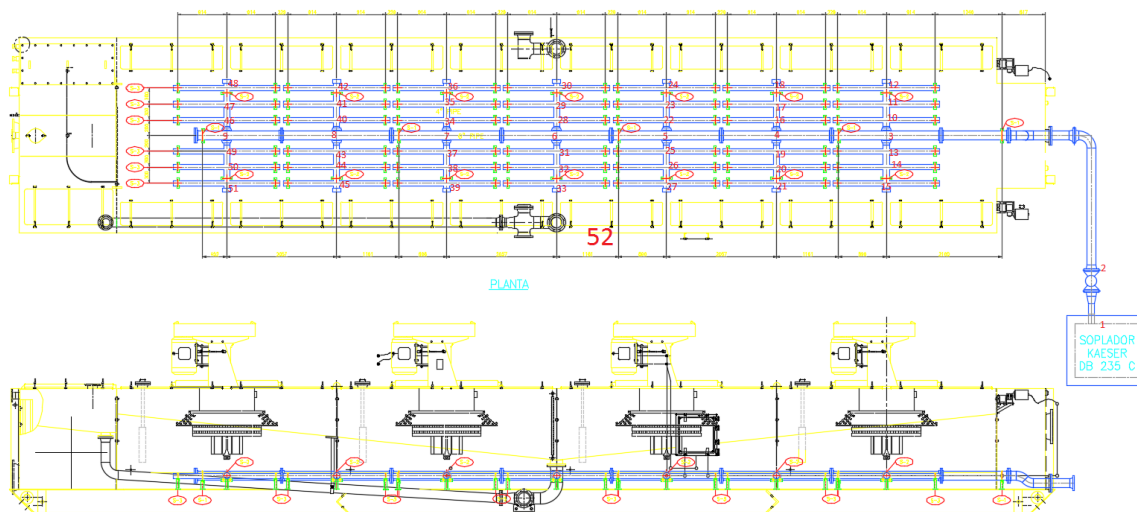


Figura 1. Distribución de tubería neumática.

3. RESULTADOS

3.1. CONDICIONES DEL ANÁLISIS:

El caudal a suministrar a cada uno de los elementos cerámicos de producción de burbujas es de magnitud aproximada de 5 SCFH según se midió en las pruebas registradas en el documento A839-OXY-WEM-MEC-P-002-Informe burbujas, de esta ingeniería. Para esta condición se presenta flujo laminar en toda la tubería del Manifold de la figura 1, según se muestra en la tabla No.1.

	CFH	GPM	m3/s	Diametro		Miu (Visc dinámica) Pa.S	Re	Recr	Régimen
Flujo Estimado por filtro	5	0.6		in	m				
Flujo en tubería principal	420	50.4	0.0033054	6.06	0.153924	1.805E-05	1,858	3,300,880	LAMINAR
Flujo en ramal	30	3.6	0.0002361	4.03	0.102235	1.805E-05	200	2,101,161	LAMINAR
Flujo en filtro	5	0.6	0.00003935	1.61	0.04094	1.805E-05	83	764,141	LAMINAR

Tabla No. 1 Régimen de flujo en tuberías de distribución.

3.2. TOPOLOGÍA DE LA RED:

Se realizó el análisis neumático utilizando los métodos planteados en los documentos indicados en el numeral 4.3. para régimen laminar.

Se escogieron diferentes configuraciones geométricas para el análisis y se determinó el caudal en cada filtro y la desviación estándar de los caudales tomando en cuenta todos los filtros según se resume en la tabla 2.

Modelo	Descripción	Desviación estándar de Q a través de los filtros [SCFH], para un caudal esperado de 5 SCFH
PF2-297-1 Actual	Es el modelo de la figura No. 1, correspondiente a lo especificado en el plano 1145763-PF2-297-1	3.56
PF2-297-1 Loop 6"	Corresponde al primer modelo modificado con una derivación a partir del nodo 2 (indicado en rojo en la figura 1), conectándolo directamente con el nodo 6 con un tubo de diámetro de 6" (tubo 2 -> 9).	1.62
PF2-297-1 Loop 4"	Igual en todo al modelo anterior excepto en que el tubo de conexión 2 -> 9 es de diámetro de 4".	2.59
PF2-297-1 6in entrando por los nodos 4 y 8	En esta configuración el tubo de entrada se conecta al nodo 4 en lugar del nodo 3 (2 -> 4) y se hace una derivación en diámetro de 6" que se conecta con el nodo 8 (2 -> 8).	1.17
PF2-297-1 4in entrando por los nodos 4 y 8	Igual en todo al modelo anterior excepto que el tubo 2 -> 8 queda en diámetro de 4".	2.19
PF2-297-1 3 tanques	Este modelo corresponde al segundo punto del alcance de este trabajo y corresponde a la ubicación de filtros solamente en 3 de los 4 tanques que componen la celda (Los primeros). En este caso la entrada se deja bifurcada en 6" entrando por los tubos 2 -> 4 y 2 -> 6 de diámetro de 6".	0.59

Tabla No. 2 comparación de uniformidad de caudales en filtros.

El cálculo de la desviación estándar de los caudales suministrados a todos los filtros se realizó ya que indica la uniformidad en la alimentación de aire a estos.

De esta manera se puede concluir que la configuración actual de los planos es inadecuada para las necesidades de suministro de aire de los filtros (productores de burbujas) presentando desviación del 71% del caudal requerido (Modelo PF2-297-1 Actual) y se mejora bajando la desviación hasta el 23% de este caudal

(Modelo PF2-297-1 6in entrando por los nodos 4 y 8), o menor si se hacen distribuciones con más derivaciones que sean viables desde el punto de vista práctico.

El modelo (PF2-297-1 3 tanques) permite predecir el comportamiento de los caudales en los filtros alimentando 3 tanques de los 4 que componen la celda.

utilizando una configuración análoga a la del mejor modelo de la celda completa (Modelo PF2-297-1 6in entrando por los nodos 4 y 8) se calculó el 12% de desviación en el caudal suministrado a los filtros.

3.2. CAUDAL Y PRESIÓN

Se realizó el cálculo neumático para el caudal nominal de trabajo de cada filtro de 5 SCFM, equivalente a 420 SCFM para toda la celda (84 filtros), o 300 SCFM para 3 tanques de 4 de la celda (60 filtros). En estas condiciones la caída de presión máxima en la tubería es del orden $O(10^{-5})$ psi, lo cual es despreciable respecto a la presión hidrostática de la altura del agua en la celda que es de 3.84 psi para nivel de 2 metros en la celda y estimando 1 psi por filtro.

4. DESCRIPCIÓN DE LOS MODELOS NEUMÁTICOS UTILIZADOS PARA EL CÁLCULO

El modelo de la red se calculó utilizando las siguientes relaciones:

$$Re = 1.5616 \frac{\dot{Q}_{st}}{\mu D} \quad (24) \text{ Ref. 2}$$

$$f_{app} Re = \frac{13.76}{(x^+)^{\frac{1}{2}}} + \frac{\frac{5}{(4x^+)} + 64 - \frac{13.76}{(x^+)^{\frac{1}{2}}}}{1 + 0.00021 (x^+)} \quad (28) \text{ Ref. 2}$$

$$(x^+) = \frac{x}{D Re} \quad (29) \text{ Ref. 2}$$

Para flujo laminar:

$$\dot{Q}_{st} = \frac{\pi}{4} \frac{1}{f_{app} Re} \frac{1}{\mu} \frac{T_{st}}{P_{st}} \left[(p_1 - p_2)^2 \frac{p_{avg}}{L T_{avg} z_{avg}} \right] D^4 \quad (87) \text{ Ref. 2}$$

Se utilizó como red de nodos con la numeración que se muestra en rojo en la figura 1, se calcularon coeficientes de pérdida, se registraron longitudes y diámetros de tuberías y se utilizó el método de las matrices NL de la referencia 1.

Para la solución de los sistemas lineales se utilizó el software Wolfram Mathematica 11.0.

5. DOCUMENTOS DE REFERENCIA

5.1 Documentos:

1. OX-WEM-P-IF-001.

2. A839-OXY-WEM-MEC-P-002-Informe burbujas.

5.2 Planos:

1. 1145763-PF2-201-2.
2. 1145763-PF2-297-1.
3. 1145763-PF2-401-1.
4. 1164977-PF2-401-3.

5.3 Referencias:

1. *Mathematica Balkanica New Series* Vol. 26, 2012, Fasc. 3-4, Gas distribution network topology problem, Dejan Brkić.
2. *Journal of the Brazilian Society of Mechanical Sciences and Engineering* On-line version ISSN 1806-3691 J. Braz. Soc. Mech. Sci. & Eng. vol.29 no.3 Rio de Janeiro July/Sept. 2007 <http://dx.doi.org/10.1590/S1678-58782007000300005>.

6. UNIDADES

7. GLOSARIO

Re = *Numero de reynolds, adimensional.*

\dot{Q}_{st} = *Flujo volumétrico de aire en condiciones estándar, m³/s.*

μ = *Viscosidad dinámica del aire Pa s.*

D = *Diámetro interno del tubo, m.*

f_{app} = *Coefficiente de darcy aparente, adimensional.*

x^+ = *Distancia de entrada en la tubería, adimensional.*

x = *Distancia de entrada en la tubería, m.*

T_{st}, T_{avg} = *Temperatura en condiciones estándar, 288.15 K.*

P_{st} = *Presión en condiciones estándar, 1.01325×10^5 Pa*

L = *Longitud del tubo, m*

z_{avg} = *Compresibilidad del gas, adimensional = 1 para operación.*

8. ANEXOS

Se anexan a este informe:

1. A843-OXY-WEM-MEC-P-003 Entradas y salidas de cálculo
2. Resultados Corridas en Mathematica:

PF2-297-1 Actual[illegible]

VectQ
VectDifP
VectDDifPDq
Cj

```
Out[66]=
{0.0033054,0.0033054,0.00249538,0.00186897,0.00137026,0.000960185,0.000609801,0.000296195,0.000405011,0.000268299,0.000133632,0.000405011,0.0
0.268299,0.000133632,0.000313203,0.000207458,0.000103338,0.000313203,0.000207458,0.000103338,0.000249357,0.000165151,0.0000822562,0.0002493
57,0.000165151,0.0000822562,0.00025038,0.000135791,0.0000676292,0.00025038,0.000135791,0.0000676292,0.000175192,0.000116022,0.0000577814,
0.000175192,0.000116022,0.0000577814,0.000156803,0.00013841,0.0000517144,0.000156803,0.00013841,0.0000517144,0.000148098,0.0000980756,0.0
0.488425,0.000148098,0.0000980756,0.000488425,0.000136711,0.000134668,0.000133632,0.000136711,0.000134668,0.000133632,0.000105745,0.00010
4119,0.000103338,0.000105745,0.000104119,0.000103338,0.0000842056,0.0000828949,0.0000822562,0.0000842056,0.0000828949,0.0000822562,0.000069
2467,0.0000681618,0.0000676292,0.0000692467,0.0000681618,0.0000676292,0.0000591705,0.0000582402,0.0000577814,0.0000591705,0.0000582402,0.0
0.0577814,0.0000529613,0.0000521268,0.0000517144,0.0000529613,0.0000521268,0.0000517144,0.0000502222,0.0000492331,0.0000488425,0.000050222
2,0.0000492331,0.0000488425}
```

[Out]67]=
0.0579588,0.0518128,0.0109239,0.00742883,0.00510055,0.00341364,0.00209686,0.000993034,0.00133877,0.000731684,0.000356693,0.00133877,0.000731
684,0.000356693,0.00101988,0.000556291,0.000273379,0.00101988,0.000556291,0.000273379,0.000805656,0.000438932,0.000216662,0.000805656,0.0004
38932,0.000216662,0.000659457,0.00035903,0.000177683,0.000659457,0.00035903,0.000177683,0.000561923,0.000305799,0.000151577,0.000561923,0.0003
05799,0.000151577,0.000502105,0.000273174,0.000135535,0.000502105,0.000273174,0.000135535,0.000473771,0.000257719,0.000127938,0.000473771,
0.000257719,0.000127938,0.0453117,0.0445801,0.0442234,0.0453117,0.0445801,0.0442234,0.0347067,0.0341504,0.033877,0.0347067,0.0341504,0.033877
0.0274921,0.0270532,0.0268365,0.0274921,0.0270532,0.0268365,0.0225378,0.0221787,0.0220211,0.0225378,0.0221787,0.0220211,0.0192217,0.0189159,0.
0187643,0.0192217,0.0189159,0.0187643,0.0171846,0.0169114,0.0167759,0.0171846,0.0169114,0.0167759,0.0162199,0.0159622,0.0158343,0.0162199,0.01
59622,0.0158343]

[illegible]

Out[69]= {-2.42861*10⁻¹⁷,7.21645*10⁻¹⁶,6.93889*10⁻¹⁸,-1.38778*10⁻¹⁷,-5.6205*10⁻¹⁶,-6.93889*10⁻¹⁸,6.93889*10⁻¹⁸,1.38778*10⁻¹⁷,0.,6.93889*10⁻¹⁸,-3.46945*10⁻¹⁸,1.04083*10⁻¹⁷,0.,-1.73472*10⁻¹⁷,1.04083*10⁻¹⁷,0.,-1.04083*10⁻¹⁷,0.,-1.73472*10⁻¹⁷,2.42861*10⁻¹⁷,3.46945*10⁻¹⁸,0.,-1.38778*10⁻¹⁷,-6.93889*10⁻¹⁸,6.245*10⁻¹⁷,-6.93889*10⁻¹⁸,-6.93889*10⁻¹⁸,1.04083*10⁻¹⁷,0.,-2.22045*10⁻¹⁶,-1.38778*10⁻¹⁷,0.,7.63278*10⁻¹⁷,-2.77556*10⁻¹⁷,1.38778*10⁻¹⁷,0.,1.31839*10⁻¹⁶,0.}

PF2-297-1 Loop 6"

```
(* Constantes *)  
R=8314.41;  
Pst=1.01325*10^5;  
Pavg=Pst+390;  
Tst= 288.15;  
Tagv=288.15;  
Miu=1.805 *10^-5;  
Zavg=1;  
  
Reynolds[Qc_,Diam_]:=1.5615*"Cq"/(Miu*Diam)  
  
(* Factor de Fricción Flujo Laminar *)  
faapRel[x_,Diam_,Qa_] := 13.76/(x*(Diam*Reynolds[Qa,Diam]))^0.5 + (5/(4*x/(Diam*Reynolds[Qa,Diam]))) + 64 - 13.76/(x/(Diam*Reynolds[Qa,Diam]))^0.5  
)/(1+(0.00021*(x/(Diam*Reynolds[Qa,Diam]))^-2))  
  
(* Caida de presión en tubos para flujo Laminar *)  
DiffP[sxmxDiami_Qi_Ld_K_] := ((4*faapRelsumx[Diami,Qid]*Miu*Pst)*(L*Tavg*Zavg)/((3.14159*Tst^2*Pavg*Diami^4))*Qi + K*0.82/Diami^2*Qi)^2  
  
(* Derivada parcial de cida de presión respecto al caudal*)  
DDiffPdQ[sumxd_Diamd_Qidd_Ld_K_] := (4*faapRel[sumxd,Diamd,Qid]*Miu*Pst)*(LdTavg*Zavg)/((3.14159*Tst^2*Pavg*Diamd^4) + K*0.82*K*Qid/Diamd^2)
```

```
Vector=  
{0.0033054,0.0016527,0.0014166,0.0011805,0.0009444,0.0007083,0.0004722,0.0002361,0.0016527,0.00011805,0.0000787,0.00003935,0.00011805,0.000078  
7,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,  
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.  
0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00003935,0.00003935,0.00003935,  
0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,  
0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,  
0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,0.00003935,
```

```
(* x+ Para cálculo de faapp x RE *)
```


[illegible]

(*Grafo del sistema*)

```
Gr1=Graph[{1->2,2->3,3->4,4->5,5->6,6->7,7->8,8->9,9->10,10->11,11->12,13->13,13->14,14->15,4->16,16->17,17->18,4->19,19->20,20->21,5->22,22->23,23->24,5->25,25->26,26->27,6->28,28->29,29->30,6->31,31->32,32->33,7->34,34->35,35->36,7->37,37->38,38->39,8->40,40->41,41->42,8->43,43->44,44->45,9->46,46->47,47->48,9->49,49->50,50->51,10->52,11->52,12->52,13->52,14->52,15->52,16->52,17->52,18->52,19->52,20->52,21->52,22->52,23->52,24->52,25->52,26->52,27->52,28->52,29->52,30->52,31->52,32->52,33->52,34->52,35->52,36->52,37->52,38->52,39->52,40->52,41->52,42->52,43->52,44->52,45->52,46->52,47->52,48->52,49->52,50->52,51->52}], VertexStyle->Orange, EdgeStyle->Green];
```

(* Matriz de incidencia *)

A0= IncidenceMatrix[Gr1];

(* Matriz nodal *)

NMatriz= Drop[IncidenceMatrix[Gr1],-1]/MatrixForm;

(* Matriz de ciclos *)

LMatriz= EdgeCycleMatrix[Gr1]/MatrixForm;

NCiclos= Length[LMatriz[[1]]];

NTubos=Length[VectQ];

NNodos= Length[VQ];

n=1;

(*Ciclo 1 *)

While[n<500,

VectDiP=Table[DiP[Vectxi[[i]],VectDiam[[i]],Abs[VectQ[[i]], VectLong[[i]], Kperd[[i]],i,NTubos];

VectDiPDq=Table[DDiPDq[Vectxi[[i]],VectDiam[[i]],Abs[VectQ[[i]], VectLong[[i]], Kperd[[i]],i,NTubos];

Li=Table[{LMatriz[[1]][i,j]]*VectDiPDq[[j]],{i,1,NCiclos},{j,1,NTubos}};

Cj=LMatriz[[1]].VectDiP;

QDf=Li.VectQ;

Cfinal=-Cj+QDf;

VQfinal=VQ;

For[j=1,j<(NCiclos+1),j++,AppendTo[VQfinal,Cfinal[[j]]];

NL=NMatriz;

For[j=1,j<(NCiclos+1),j++,AppendTo[NL[[1]],Li[[j]]];

For[i=1,i<(NCiclos+1),i++, For[j=1,j<(NTubos+1),j++, If[VectQ[[j]]<0,Li[[i,j]]=-1 * Li[[i,j]], Li[[i,j]]=Li[[i,j]]];

VectQ=LinearSolve[NL[[1]],VQfinal];

n++

}

(* LAS SIGUIENTES APARECEN EN SALIDAS EN SU ORDEN *)

(*Caudal en cada tubo*)

VectQ

(*Caida de presión en etubo *)

VectDiP

VectDiPDq

(* Criterio de Convergencia ->0 Cj *)

Cj

(*Salidas*)

```
Out[177]= {0.0033054,0.00275715,0.00203836,0.00146354,0.000985115,0.000568221,0.000185384,-  
0.000186821,0.000548252,0.000359395,0.000238072,0.000118574,0.000359395,0.000238072,0.000118574,0.000287407,0.000190367,0.0000948235,0.0002  
87407,0.000190367,0.0000948235,0.000239214,0.000158433,0.0000789095,0.000239214,0.000158433,0.0000789095,0.000208447,0.000138049,0.00006875  
4,0.000208447,0.000138049,0.000068754,0.000191419,0.000126768,0.000063134,0.000191419,0.000126768,0.000063134,0.000186103,0.000123246,0.0000  
61379,0.000186103,0.000123246,0.000061379,0.000180715,0.000119677,0.0000596009,0.000180715,0.000119677,0.0000596009,0.000121323,0.000119498  
0.000118574,0.000121323,0.000119498,0.000118574,0.0000970395,0.0000955439,0.0000948235,0.0000970395,0.0000955439,0.0000948235,0.0000807816  
0.0000795232,0.0000789095,0.0000807816,0.0000795232,0.0000789095,0.0000703979,0.0000692952,0.000068754,0.0000703979,0.0000692952,0.0000687  
54,0.0000646502,0.0000636344,0.000063134,0.0000646502,0.0000636344,0.000063134,0.0000628565,0.0000618673,0.000061379,0.0000628565,0.0000618  
673,0.000061379,0.0000610382,0.000060763,0.0000596009,0.0000610382,0.000060763,0.0000596009}
```

Out[179]=

```
{0.0579588,0.0423889,0.0085379,0.00560692,0.00354924,0.00195858,0.000617782,0.000621715,0.063281,0.00118309,0.000646196,0.000315735,0.0011830  
9,0.000646196,0.000315735,0.000934145,0.000509376,0.000250587,0.000934145,0.000509376,0.000250587,0.000772415,0.00042078,0.000207775,0.00077  
2415,0.00042078,0.000207775,0.000670541,0.000365076,0.000180656,0.000670541,0.000365076,0.000180656,0.000614421,0.000334409,0.000165688,0.00  
0614421,0.000334409,0.000165688,0.000596633,0.000324667,0.000160973,0.000596633,0.000324667,0.000160973,0.000578799,0.000314914,0.000156225  
0.000578799,0.000314914,0.000156225,0.0400969,0.0394507,0.039135,0.0400969,0.0394507,0.039135,0.0318079,0.0312986,0.031048,0.0318079,0.031298  
6,0.031048,0.0263627,0.025942,0.0257342,0.0263627,0.025942,0.0257342,0.0229154,0.0225503,0.0223696,0.0229154,0.0225503,0.0223696,0.0210129,0.02  
06785,0.0205128,0.0210129,0.0206785,0.0205128,0.0204129,0.0200882,0.0199273,0.0204129,0.0200882,0.0199273,0.019809,0.0194941,0.0193379,0.01980  
9,0.0194941,0.0193379}
```

Out[180]=

```
{17.5346,15.3742,4.18862,3.83106,3.60287,3.44686,3.33245,3.32786,1.15423,3.29188,2.71429,2.66276,3.29188,2.71429,2.66276,3.25025,2.67575,2.64267,3.  
25025,2.67575,2.64267,3.22897,2.65589,2.63308,3.22897,2.65589,2.63308,3.21684,2.64453,2.62757,3.21684,2.64453,2.62757,3.20983,2.63795,2.62438,3.20  
983,2.63795,2.62438,3.20593,2.63429,2.6226,3.20593,2.63429,2.6226,3.20282,2.63137,2.62118,3.20282,2.63137,2.62118,330.497,330.138,330.046,330.497,  
330.138,330.046,327.783,327.583,327.429,327.783,327.583,327.429,326.346,326.219,326.123,326.346,326.219,326.123,325.512,325.423,325.358,325.512,32  
5.423,325.358,325.025,324.958,324.909,325.025,324.958,324.909,324.754,324.699,324.66,324.754,324.699,324.66,324.535,324.489,324.457,324.535,324.48  
9,324.457}
```

Out[182]=

```
{-1.38778*10^-17,-1.94289*10^-16,1.38778*10^-17,1.04083*10^-17,1.76942*10^-16,1.38778*10^-17,0.,6.93889*10^-18,-1.04083*10^-17,-  
3.46945*10^-18,-7.28584*10^-17,0.,-3.46945*10^-18,-3.1225*10^-17,-1.73472*10^-17,-3.46945*10^-18,4.85723*10^-17,6.93889*10^-18,-6.93889*10^-  
18,1.04083*10^-17,-3.46945*10^-18,-6.93889*10^-18,3.81639*10^-17,-3.46945*10^-18,0.,-1.04083*10^-17,-3.46945*10^-18,6.93889*10^-18,3.46945*10^-  
18,1.04083*10^-17,-6.93889*10^-18,1.52656*10^-16,-6.93889*10^-18,3.46945*10^-18,-9.02056*10^-17,6.93889*10^-18,0.,-6.93889*10^-18,6.93889*10^-  
18,0.,1.38778*10^-17}
```

PF2-297-1 6in entrando por los nodos 4 y 8

(*Constantes*)

R=8314.41;

Pst=1.01325*10^5;

Pavg=Pst+390;

Tst= 288.15;

Tavg=288.15;

Miu=1.805 *10^-5;

Zavg=1;

12

```

VectQ=LinearSolve[NL[[1]],VQfinal];
n++
]
(* LAS SIGUIENTES APARECEN EN SALIDAS EN SU ORDEN *)
(*Caudal en cada tubo*)
VectQ
(*Caída de presión en etubo *)
VectDiffP
VectDDifPDq
(* Criterio de Convergencia ->0 Cj *)
Cj
(*Salidas*)

Out[412]=
{0.0033054,0.00201249,-0.000566809,0.000911681,0.000434281,-0.0000177029,-
0.00046911,0.000400122,0.00129291,0.000283404,0.000187722,0.000093494,0.000283404,0.000187722,0.000093494,0.000267002,0.000176849,0.0000880
885,0.000267002,0.000176849,0.0000880885,0.0002387,0.000158092,0.0000787398,0.0002387,0.000158092,0.0000787398,0.000225992,0.00014967,0.0000
745421,0.000225992,0.00014967,0.0000745421,0.000225703,0.000149476,0.0000744439,0.000225703,0.000149476,0.0000744439,0.000211837,0.00014029
,0.0000698677,0.000211837,0.00014029,0.0000698677,0.000200061,0.000132489,0.0000659818,0.000200061,0.000132489,0.0000659818,0.0000956828,0.0
000942277,0.000093494,0.0000956828,0.0000942277,0.000093494,0.0000901529,0.0000887607,0.0000880885,0.0000901529,0.0000887607,0.0000880885,
0.000080608,0.0000793523,0.0000787398,0.000080608,0.0000793523,0.0000787398,0.000076322,0.0000751277,0.0000745421,0.000076322,0.0000751277,
0.0000745421,0.0000762277,0.0000750318,0.0000744439,0.0000762277,0.0000750318,0.0000744439,0.0000715473,0.0000704223,0.0000698677,0.000071
5473,0.0000704223,0.0000698677,0.0000675716,0.0000665074,0.0000659818,0.0000675716,0.0000665074,0.0000659818}

Out[414]=
{0.0579588,0.0295681,0.00201183,0.00331037,0.00148866,0.0000582472,0.00159671,0.00135082,0.0360221,0.000926461,0.000505499,0.000247943,0.0009
26461,0.000505499,0.000247943,0.000866546,0.000472405,0.000232594,0.000866546,0.000472405,0.000232594,0.00077073,0.00041986,0.000207324,0.00
77073,0.00041986,0.000207324,0.00072764,0.000396222,0.000195966,0.00072764,0.000396222,0.000195966,0.000725594,0.000395018,0.000195543,0.00
0725594,0.000395018,0.000195543,0.000679838,0.000370008,0.000183344,0.000679838,0.000370008,0.000183344,0.000641207,0.000348911,0.00017302,
0.000641207,0.000348911,0.00017302,0.031472,0.0309665,0.0307185,0.031472,0.0309665,0.0307185,0.0295201,0.0290477,0.0288151,0.0295201,0.029047
7,0.0288151,0.0263055,0.0258856,0.0256783,0.0263055,0.0258856,0.0256783,0.0248599,0.0244637,0.0242677,0.0248599,0.0244637,0.0242677,0.0248037,
0.0244087,0.0242132,0.0248037,0.0244087,0.0242132,0.0232528,0.0228828,0.0226994,0.0232528,0.0228828,0.0226994,0.0219406,0.0215917,0.0214187,0.
0219406,0.0215917,0.0214187}

Out[415]=
{17.5346,14.6923,3.5494,3.63106,3.42789,3.29027,3.4037,3.37602,27.8613,3.26904,2.69281,2.65197,3.26904,2.69281,2.65197,3.24546,2.67123,2.64046,3.24
546,2.67123,2.64046,3.22886,2.65579,2.63303,3.22886,2.65579,2.63303,3.21976,2.64731,2.62894,3.21976,2.64731,2.62894,3.21481,2.64269,2.62671,3.2148
1,2.64269,2.62671,3.20925,2.63745,2.62416,3.20925,2.63745,2.62416,3.20506,2.6335,2.62223,3.20506,2.6335,2.62223,328.92,328.635,328.562,328.92,328.6
35,328.562,327.444,327.258,327.115,327.444,327.258,327.115,326.339,326.212,326.116,326.339,326.212,326.116,325.724,325.628,325.557,325.724,325.628
,325.557,325.39,325.311,325.254,325.39,325.311,325.254,324.999,324.936,324.891,324.999,324.936,324.891,324.701,324.651,324.614,324.701,324.651,324.
614}

Out[417]=
{-3.46945*10^-18,6.93889*10^-18,-1.04083*10^-17,-3.46945*10^-18,0,-3.46945*10^-18,3.46945*10^-18,3.46945*10^-18,-6.93889*10^-18,-
6.93889*10^-18,1.04083*10^-17,-6.93889*10^-18,3.46945*10^-18,-6.93889*10^-18,-6.93889*10^-18,3.46945*10^-18,-3.46945*10^-18,-3.46945*10^-18,-
3.46945*10^-18,0,-3.46945*10^-18,0,-1.04083*10^-17,0,-3.46945*10^-18,-
6.93889*10^-18,-3.46945*10^-18,3.46945*10^-18,0,-3.46945*10^-18,-1.04083*10^-17,-6.93889*10^-18,0,-1.04083*10^-17,0,-2.08167*10^-17}


```

PF2-297-1 4in entrando por los nodos 4 y 8

```

(*Constantes*)
R=8314.41;
Pst=1.01325*10^5;
Pavg=Pst+390;
Tst= 288.15;
Tavg=288.15;
Miu=1.805 *10^-5;
Zavg=1;
Reynolds[Qc_,Diam_]:=1.5615*Qc/(Miu*Diam)
(* Factor de Fricción Flujo Laminar *)
faapRe[x_,Diam_,Qa_]:= 13.76/(x*(Diam*Reynolds[Qa,Diam]))^0.5 + (5/(4*x*(Diam*Reynolds[Qa,Diam]))+64-13.76/(x*(Diam*Reynolds[Qa,Diam]))^0.5
)/(1+0.00021*(x*(Diam*Reynolds[Qa,Diam]))^2)
(*Caída de presión en tubos para flujo Laminar *)
DiffP[sumx_,Diami_,Qi_,L_,K_]:=((4*faapRe[sumx,Diami,Qi]*Miu*Pst)*(L*Tavg*Zavg)/(3.14159*Tst^2*Pavg*Diami^4))*Qi+K*0.82/Diami^2*Qi^2
(*Derivada parcial de cida de presión respecto al caudal*)
DDifPDq[sumxd_,Diamd_,Qid_,Ld_,K_]:= (4*faapRe[sumxd,Diamd,Qid]*Miu*Pst)*(Ld*Tavg*Zavg)/(3.14159*Tst^2*Pavg*Diamd^4)+K*0.82*2*Qid/Diamd^2
(* Caudales iniciales *)

VectQ=
{0.0033054,0.0016527,0.0014166,0.0011805,0.0009444,0.0007083,0.0004722,0.0002361,0.0016527,0.00011805,0.0000787,0.00003935,0.00011805,0.000078
7,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,
0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,
0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,
0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.00003935,0.00011805,0.0000787,0.0
```

[Out[532]]=
[17.5346, 16.0534, 3.58227, 3.8664, 3.62745, 3.46462, 3.34578, 3.36677, 115.606, 3.27998, 2.70309, 2.65713, 3.27998, 2.70309, 2.65713, 3.25349, 2.67882, 2.64417, 3.2
5349, 2.67882, 2.64417, 3.23095, 2.65777, 2.634, 3.23095, 2.65777, 2.634, 3.21809, 2.64572, 2.62816, 3.21809, 2.64572, 2.62816, 3.21063, 2.63871, 2.62475, 3.21063, 2.
63871, 2.62475, 3.20644, 2.63477, 2.62284, 3.20644, 2.63477, 2.62284, 3.20628, 2.63123, 2.62111, 3.20268, 2.63123, 2.62111, 3.20674, 3.29, 354, 3.29, 354, 3.29, 354, 3.29,
354, 329, 272, 328, 013, 327, 803, 327, 644, 328, 013, 327, 803, 327, 644, 328, 356, 326, 556, 326, 488, 326, 556, 326, 556, 326, 556, 326, 556, 326, 556, 326, 556, 326, 556, 326, 556,

Out[534]= {2.42861*10^-17, 1.04083*10^-17, -6.93889*10^-18, 0., -6.93889*10^-18, -1.04083*10^-17, -6.93889*10^-18, -1.38778*10^-17, -3.46945*10^-18, -6.93889*10^-18, 3.46945*10^-18, 0., -3.46945*10^-18, 0., -6.93889*10^-18, -1.73472*10^-17, -6.93889*10^-18, -1.04083*10^-17, 0., -6.93889*10^-18, -3.46945*10^-18, -6.93889*10^-18, 0., -1.04083*10^-17, -6.93889*10^-18, -6.93889*10^-18, -6.93889*10^-18, 6.93889*10^-18, 6.93889*10^-18, 0., -6.93889*10^-18, -6.93889*10^-18, 0., 0., -1.66533*10^-16}

```

NNodos= Length[VQ];

```

```

n=1;
(*Ciclo 1 *)
While[n<500,
VectDifP=Table[DifP[Vectxi[[i]],VectDiam[[i]],Abs[VectQ[[i]]], VectLong[[i]], Kperd[[i]],{i,NTubos}];
VectDDifPDq=Table[DDifPDq[Vectxi[[i]],VectDiam[[i]],Abs[VectQ[[i]]], VectLong[[i]], Kperd[[i]],{i,NTubos}];
Li=Table[(LMatriz[[1]][[i,j]]*VectDDifPDq[[i]]),{i,1,NCiclos},{j,1,NTubos}];
Cj=LMatriz[[1]].VectDifP;
QDf=Li.VectQ;
Cfinal=-Cj+QDf;
VQfinal=VQ;
For[j=1,j<(NCiclos+1),j++,AppendTo[VQfinal,Cfinal[[j]]];
NL=NMatriz;
For[j=1,j<(NCiclos+1),j++,AppendTo[NL[[1]],Li[[j]]];
For[i=1,i<(NCiclos+1),i++, For[j=1,j<(NTubos+1),j++, If[VectQ[[j]]<0,Li[[i,j]]=-1 * Li[[i,j]], Li[[i,j]]=Li[[i,j]]];
VectQ=LinearSolve[NL[[1]],VQfinal];
n++;
]
(* LAS SIGUIENTES APARECEN EN SALIDAS EN SU ORDEN *)
(*Caudal en cada tubo*)
VectQ
(*Caída de presión en etubo *)
VectDifP
VectDDifPDq
(* Criterio de Convergencia ->0 Cj *)
Cj
(*Salidas*)

Out[653]=
{0.002361,0.00132413,-0.000515703,0.000322877,-
0.000144174,0.00043359,0.00103687,0.000257851,0.00017078,0.0000850533,0.000257851,0.00017078,0.0000850533,0.000242773,0.00016079,0.00008008
38,0.000242773,0.00016079,0.0000800838,0.000233525,0.00015466,0.0000770276,0.000233525,0.00015466,0.0000770276,0.000229555,0.000152027,0.000
0757146,0.000229555,0.000152027,0.0000757146,0.000216795,0.000143574,0.0000715032,0.000216795,0.000143574,0.0000715032,0.0000870714,0.00008
57267,0.0000850533,0.0000870714,0.0000857267,0.0000850533,0.0000819829,0.0000807062,0.0000800838,0.0000819829,0.0000807062,0.0000800838,0.0
000788657,0.0000776321,0.0000770276,0.0000788657,0.0000776321,0.0000770276,0.0000775283,0.0000763123,0.0000757146,0.0000775283,0.000076312
3,0.0000757146,0.0000732216,0.0000720705,0.0000715032,0.0000732216,0.0000720705,0.0000715032}

Out[655]=
{0.0360149,0.0214417,0.00179662,0.00109513,0.000479641,0.00147198,0.0230165,0.000836543,0.000455997,0.000224593,0.000836543,0.000455997,0.000
224593,0.000784077,0.000427148,0.000210893,0.000784077,0.000427148,0.000210893,0.000752191,0.000409617,0.000202546,0.000752191,0.000409617,
0.000202546,0.000738106,0.000401842,0.0001989,0.000738106,0.000401842,0.0001989,0.000695888,0.000378756,0.000187657,0.000695888,0.000378756,
0.000187657,0.0285031,0.0280471,0.0278225,0.0285031,0.0280471,0.0278225,0.0267589,0.0263318,0.0261209,0.0267589,0.0263318,0.0261209,0.0256957,
0.0252861,0.0250835,0.0256957,0.0252861,0.0250835,0.0252302,0.0248283,0.0246294,0.0252302,0.0248283,0.0246294,0.0238004,0.0234216,0.023234,0.0
238004,0.0234216,0.023234}

Out[656]=
{15.2541,16.1931,3.48384,3.39178,3.32683,3.39487,22.1979,3.24428,2.67008,2.64061,3.24428,2.67008,2.64061,3.22967,2.65656,2.6334,3.22967,2.65656,2.6
334,3.22102,2.64851,2.62953,3.22102,2.64851,2.62953,3.21538,2.64323,2.62697,3.21538,2.64323,2.62697,3.20989,2.63806,2.62446,3.20989,2.63806,2.6244
6,327.353,327.169,327.119,327.353,327.169,327.119,326.397,326.267,326.17,326.397,326.267,326.17,325.816,325.717,325.644,325.816,325.717,325.644,32
5.432,325.351,325.293,325.432,325.351,325.293,325.046,324.982,324.936,325.046,324.982,324.936}

Out[658]=
{-3.46945*10^-18,-3.46945*10^-18,6.93889*10^-18,-2.08167*10^-17,-1.04083*10^-17,-1.04083*10^-17,-1.73472*10^-17,6.93889*10^-18,-
3.46945*10^-18,-2.08167*10^-17,0,-3.46945*10^-18,-3.46945*10^-18,-6.93889*10^-18,-3.46945*10^-18,0,-3.46945*10^-18,3.46945*10^-18,3.46945*10^-
18,0,-3.46945*10^-18,0,0,-3.46945*10^-18,0,0,0,-3.46945*10^-17}

```