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OPTIMISATION OF LONG DISTANCE GAS PIPELINE PROJECTS

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WORLD GAS CONFERENCE

OPTIMISATION OF GAS PIPELINE PROJECTS

- 1st Question: How to define the basic parameters of a gas pipeline, i.e. diameter (D) Maximum Operating Pressure (P_1) Number of Compressor Plants (X) and Compression Ratio (P_1/P_2), optimizing these variables?

- 2nd Question: How to teach new engineers the principles of gas transmission and gas pipeline design, with the purpose of inserting them into the gas industry?

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OPTIMISATION OF GAS PIPELINE PROJECT

- The method was developed for the design of different gas pipelines during the professional activities of the authors of this paper.
- Simultaneously, the method was applied to teach gas pipeline design principles to young engineers taking the postgraduate course of Specialization in Natural Gas at the University of Buenos Aires (UBA).
- The part of gas pipeline optimisation here presented is only one case of those developed by the authors for the projects of oil pipelines, multi-product pipelines, aqueducts and slurry pipelines.

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OPTIMISATION OF GAS PIPELINE PROJECT

The main objective of the method here presented is to explain how to transport natural gas over long-distance pipelines, at minimal costs (investment and operation cost), applying a relatively simple calculation methodology to find the optimum project with minimum analysis of alternative projects

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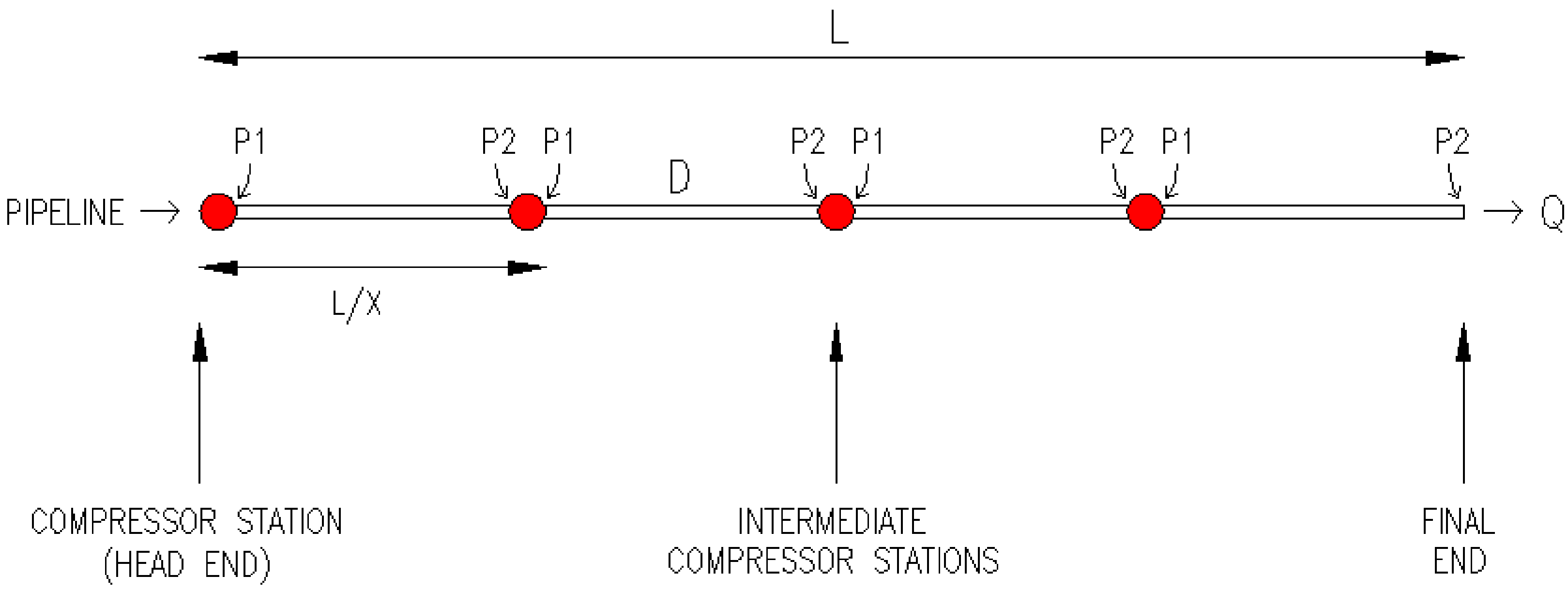
SCHEMATIC GAS PIPELINE



SCHEMATIC GAS PIPELINE SYSTEM

COST FUNCTIONS

- C_1 = cost of Pipeline (pipe, valves, fittings)
- C_2 = cost of Energy required for Compressors
- C_3 = cost of Compressor Stations
- C_4 = cost of Gas required for Filling pipeline

- <u>TOTAL COST</u>:

$$C_T = f_t\,(D, P1, X, P1/P2) = C_1+C_2+C_3+C_4$$

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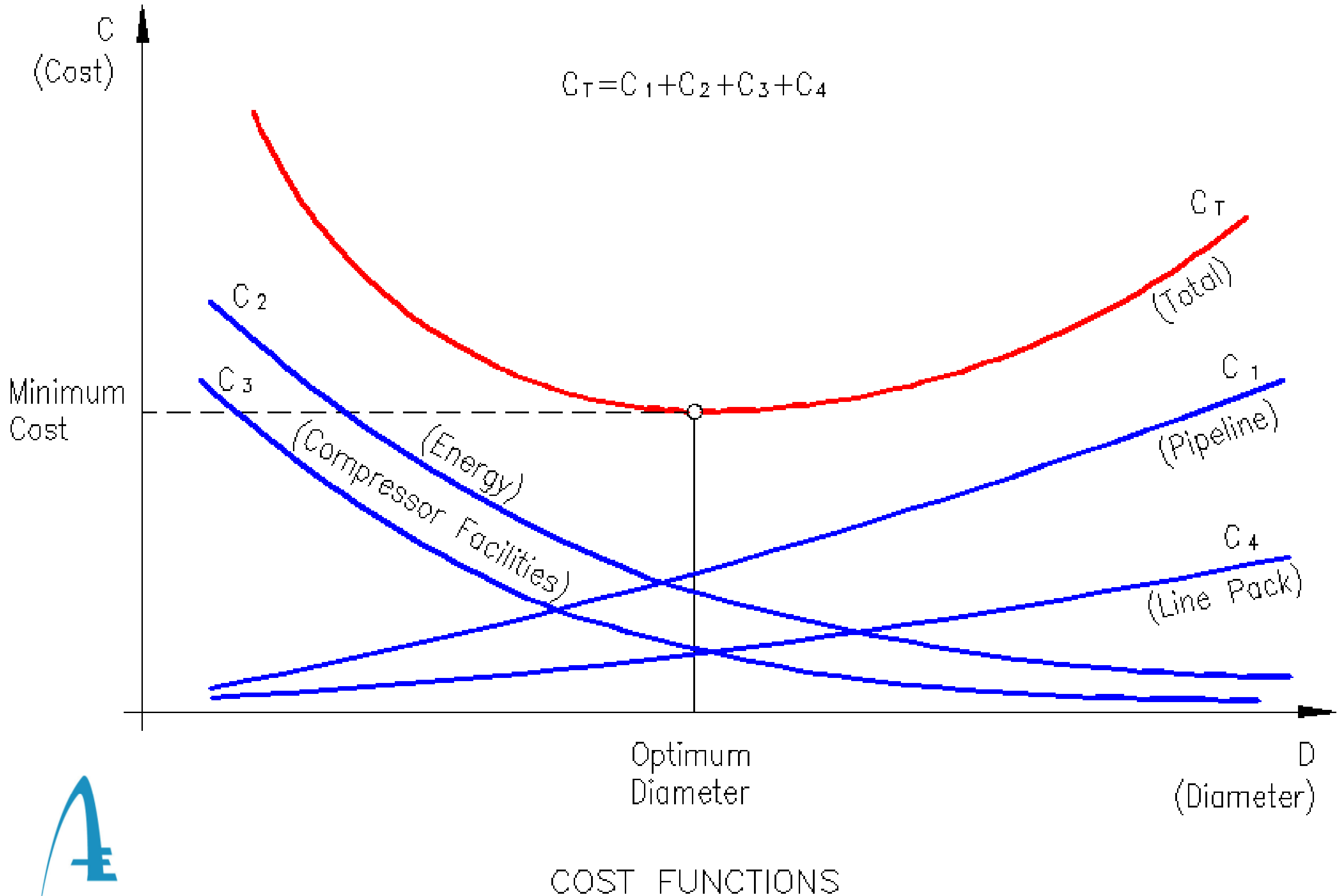
COST FUNCTIONS GRAPH



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ISOTHERMAL FLOW EQUATION

$$C_\rho^2 = \frac{\pi^2}{16}\frac{D_i^5 \chi}{RTfL}\left(P_1^2 - P_2^2\right) = \frac{\pi^2}{16}\frac{D_i^5 P_1^2 \chi}{RTfL}\left[1 - \left(\frac{P_1}{P_2}\right)^{-2}\right]$$

$$C_T = f\left(D, P_1, \frac{P_1}{P_2}, \chi\right) \qquad \text{(cost function)}$$

$$\varphi = C_\rho{}^2 - \frac{\pi^2}{16}\frac{K_D^5 D^5 P_1^2 \chi}{RTfL}\left[1 - \left(\frac{P_1}{P_2}\right)^{-2}\right] = 0 \qquad \text{(border condition equation)}$$

LAGRANGE SYSTEM (with λ Lagrange multiplier)

1) $$\frac{\partial C_T}{\partial D} + \lambda \frac{\partial \varphi}{\partial D} = 0$$

2) $$\frac{\partial C_T}{\partial P_1} + \lambda \frac{\partial \varphi}{\partial P_1} = 0$$

3) $$\frac{\partial C_T}{\partial \left(\frac{P_1}{P_2}\right)} + \lambda \frac{\partial \varphi}{\partial \left(\frac{P_1}{P_2}\right)} = 0$$

4) $$\frac{\partial C_T}{\partial \chi} + \lambda \frac{\partial \varphi}{\partial \chi} = 0$$

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OPTIMIZATION METODOLOGY

- Applying the Lagrange Multiplier Method to the Total Cost, under the condition of meeting the isothermal flow equation, it results in a system of five equations and five unknown values (D, X, P_1, P_1/P_2, λ); where λ is the Lagrange multiplier .

- When solving the system, λ is eliminated and the related minimums of Diameter, Number of Compressor Plants, Maximum Operating Pressure and Compression Ratio in Compressor Plants are obtained.

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MATHEMATICAL FUNCTIONS

$$\left(\frac{K_{02}K_2 t}{\eta_m \eta_i}+\frac{K_3}{\eta_i}\right)C_\rho RT\left\{\frac{1}{2}\left(\frac{P_1}{P_2}\right)^{\frac{K-1}{K}}\left[\left(\frac{P_1}{P_2}\right)^2-\frac{3K-1}{K-1}\right]+\frac{K}{K-1}\right\}-K_{03}=0$$

$$D=\left\langle\left\{\frac{K}{K-1}\left(\frac{K_{02}K_2 t}{\eta_m \eta_c}+\frac{K_3}{\eta_c}\right)C_\rho RT\left[\left(\frac{P_1}{P_2}\right)^{\frac{K-1}{K}}-1\right]+K_{03}\right\}\frac{\left(K_{11}\frac{1+K_D}{8\sigma}\gamma_f+\frac{K_{04}K_4K_D^2}{9RT}\right)^2}{\left[\pi\left(K_{12}+K_{13}\right)\right]^3}\frac{16C_\rho^2 RTf}{K_D^5\left[1-\left(\frac{P_1}{P_2}\right)^{-2}\right]}\right\rangle^{\frac{1}{4}}$$

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MATHEMATICAL FUNCTIONS

$$P_1 = \frac{K_{12} + K_{13}}{\left(K_{11} \frac{1 + K_D}{8} \frac{\gamma_f}{\sigma_{ad}} + \frac{K_{04} K_4 K_D^2}{9RT} \right) D}$$

$$\chi = \frac{16 C_\rho^2}{\pi^2 K_D{}^5} \frac{RTfL}{D^5 P_1^2 \left[1 - \left(\frac{P_1}{P_2} \right)^{-2} \right]}$$

SOLUTION

- To begin solving the case, from equation (I) the **compression ratio** is obtained; then with this pressure equation ratio from equation (II) the outer **diameter D** is obtained. Afterwards, from equation (III) the pipe **maximum pressure** is obtained and from equation (IV), the **number of compressor** stations is obtained.

PRACTICAL ADJUSTEMENT OF THE RESULTS

- Considering that from the theoretical formulation the variables D and P_1 as well as theoretical thickness are obtained, manufacture standard dimensions must be selected.
- Same operations must be conducted on the result of X, (i.e. the number of plants), which must be a discrete number.
- In this way, the main definitions of the new pipeline (size and compressors facilities and power involved) are established with a single analysis

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CONCLUSIONS

- The proposed methodology strives to comply with the requirements of information, rationality and effective calculation possibilities, since most of the data used is already in the databases usually available in companies.

- Given the utmost importance that the gas pipeline networks have for the gas industry as a whole, all the effort put into achieving a greater economic rationale when designing a new system will never be too much.

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Final Comment

- Engineers increasingly better trained and skilled will make gas industry increase more and better.

Thank you all for attending!

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