OPTIMIZATION OF THERMAL ENERGY TRANSPORTATION EXECUTED IN LONG PIPES

Sead Delalic and Amir Aranutovic,
Faculty of Mechanical Engineering
University of Tuzla
Franjevačka 2,
Tuzla, 75000
Bosnia and Herzegovina

Sandira Alagic
Faculty of Mechanical Engineering
University of Tuzla
Franjevačka 2,
Tuzla, 75000
Bosnia and Herzegovina

ABSTRACT

Fluids, steam and gas carry out thermal energy transportation by long pipes as energy bearers. This transportation is associated with complex problems, where the special issue is optimization of pipe systems. This optimization should find optimum ratio between physical parameters of transportation, environment state and economical parameters.

In this work, partial optimization of hydraulic parameters in pipeline systems is made in example of thermal energy for Tuzla city from Power Plant "Tuzla " BiH.

INTRODUCTION

From the point of safe and economical exploitation, transportation of thermal energy in the long distance heating system of Tuzla town doesn't always function in optimum hydraulic regime. Knowing hydraulic parameters of the pipe system in different working regimes, it is possible to determine required conditions for the optimum transportation of thermal energy from the point of having minimized transportation costs and safe and regular distribution of thermal energy to all users. Tuzla Town is energetic user of thermal energy for public needs (heating of apartments, offices and partly for preparations of sanitary water). On the basis of previously done projects, studies and analysis, it has been decided that Tuzla Power Plant was the best solution as the long-term thermal energy supplier.

BASIC CHARACTERISTICS OF LONG DISTANCE HEATING SYSTEM OF TUZLA TOWN

Transportation system for thermal energy supply of Tuzla town consists of the following elements:

- Pump station with three centrifugal pumps of the same kind, with one of them having constant number of rpm, while two have a possibility for change in rpm regulating in that way the amount of transported water;
- Heat consumers are connected via indirect exchange stations except for the users in "Slatina", who are connected directly to the hot water pipeline via mix-station. Equipment for pressure and flow reduction is installed in users' heat stations.

Main hot water pipeline that connects heat source in Tuzla Power Plant and users in Tuzla town is 11km long.

Projected temperatures of heat carriers in outgoing and returning pipeline are 145/75°C for the environment temperature -17°C. Regulation of heat transportation is qualitative i.e. heat loading is regulated by temperature change of heat carrier keeping the same flow. Capacity of the net is 220 MW with flow of 2794 m^3/h.

MODEL OF HEATING DISTRIBUTION NET IN TUZLA TOWN

Model of the heating distribution net for Tuzla town is shown on Fig. 1. Control of hydraulic parameters in pipeline net is made for stationary states and for the following working regimes:

- Calculation of pipeline net when water flows are known, on the basis of users'heat load with an EXCEl programme due to check up of the model, analysis of flow and determinating of optimum working points;
- calcualtion of pipeline net using Hardy Cross method with a FORTRAN programme due to analysis and optimization of hydraulic parameters.

Optimum working point defining of the system is made for two cases:

- when one user is cut off (user no. 59 – Slatina),
- when the pump pressure is increased due to flow increase for all users.

A computer programme for calculation of hydraulic system's steady state takes into consideration characteristics of hydraullic parameters in pipeline system and circulation pumps, and calculates, by iteration, optimum working point of the system.

A pump characteristic is determined by interpolation method of the third grade polinom using the least square method.

$$z = (y_i - y)^2 \rightarrow min \quad (1)$$

where y_i are ordinates of measured points and y are calculated values of approximations. In order to define a characteristic curve of the pump, it is necessary to determine value of hydraulic pressure as a function of flow in four working points. Since the polinom is defined knowing coefficients C_1, C_2, C_3, and C_4, it can be presented as:

$$y = p(x) = C_1 + C_2 x + C_3 x^2 + C_4 x^3 \quad (2)$$

i.e.

$$H_p(V') = C_1 + C_2 V' + C_3 V'^2 + C_4 V'^3 \quad (3)$$

On the basis of the above metioned, the condition of smallest deviations is :

$$z = \sum \left(y_i - C_1 - C_2 x - C_3 x^2 - C_4 x^3\right)^2 \rightarrow min \quad (4)$$

This deviation will have the smallest value if a system of differential equations, which is result of partial derivations of coefficients C_1, while coefficients C_1 are calculated by approximations, is solved. Then as a result there is a system of linear algebraic equations. The system of linear algebraic equations can be presente in a matrix and solved by Gauss eliminations.

$$\begin{vmatrix} 1 & x_1 & x_1^2 & x_1^3 \\ 1 & x_2 & x_2^2 & x_2^3 \\ 1 & x_3 & x_3^2 & x_3^3 \\ 1 & x_4 & x_4^2 & x_4^3 \end{vmatrix} \begin{vmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{vmatrix} = \begin{vmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{vmatrix} \quad (5)$$

At the end, the computer programme presents values of C_i and creates a cubic equation for the characteristics pump curve.

$$H_p = C_1 + C_2 V' + C_3 V'^2 + C_4 V'^3 \quad (6)$$

A pipeline characteristic curve is determined in the same way if at least three working points are known, with values of hydraulic head as a function of flow.

ANALYSIS OF RESULTS

Calculation results for the pipeline and for six different flows are shown in Fig. 2. Deviations of measured values are up to 4% bigger then the calculated values with measuring error up to 1.5 %. For current exploitation conditions with a water flow approx. 2174 m^3/h, velocities and pressure drops in pipes are smaller then optimum values. Calculated velocities are 1.1-1.2 m/s while the optimum velocity for the mentioned system is 2.8 m/s. Values of water velocities and pressure drops are closest to the optimum values for the flow of 2794 m^3/h which is equal to thermal loading of 220 MW. However, as shown on Fig. 3, projected capacity of hot water pipeline can not be reached with existing pumps capacity and pipeline characteristic. The system's working reagime curve shown on Fig. 3 gives the best approximation of optimum working points 1-6 and its analytical equation is the second kind of polinom.

Calculation results using Hardy Cross method, for different system's working reagimes are shown on Fig. 4, Fig. 5 and Fig.6., when user No. 59 ("Slatina") is cut off, characteristic of pipeline resistance is increased with resulting decrease of total flow of the pipeline system (working points 1 and 2, Fig. 6). Distribution of pressures is unsymetric, users get flow which is different from the projected one, while the functioning of pipeline system is out of optimum range (Fig. 4).

In order to have the system working in optimum reagime (working point 3, Fig. 6), it is necessary to change a hydraulics characteristic of the whole system by changing the working characteristic of the pumps and pipeline resistance. Defining procedure for optimum working point of the system includes the following phases:

- hydraulics calculation of the working state for thermal capacity 169.8 MW and flow 0.604 m^3/s with defined pump characteristic (working point 1, Fig. 6),
- when user No. 59 ("Slatina") is cut off, with the same pump characteristic, the system comes to working point 2 (Fig. 6) and as a result there is unsymetric pressure distribution and unproporcional flow changes registrated by users,
- in order to optimize the system it is necessary to decrease pump pressure which is in accordance with working point 3.

Defining of the system's optimum working point, in case when the flow needs to be increased for all users, is made on the example of increase in system load from 169.8 MW (with the flow 0.604 m^3/s) to 185.9 MW (with the flow 0.662 m^3/s) and it is given by working points 1 and 4 (Fig. 6).

Pressure distribution has become unsymetric and resulting flow changes for some users are unproportional. Users closer to pump station have got increased flow, while those far away from the pump station have got decreased flow.

CONCLUSION:

- Long distance heating system for Tuzla town doesn't work in optimum reagime so the energy losses are quite big.
- Small disturbances in the system bring the system in unstabil state and there are no means to quickly return it to previous state.
- System regulation by increase of water temperature in the hot water pipeline is the worst solution from the point of energy exploitation.

REFERENCES:

(Book)

Demirdžić I.& other,1990, *Računari u inženjerstvu*, Sarajevo.

Koharić V.,1982, *Uvod u projektovanje cjevovoda*, Fakultet strojarstva i brodogradnje Sveučilišta u Zagrebu.

Kozin V.E. & other, 1980, *Toplosnabzenie*, Moskva.

Streeter L.V.& Wylie E.B., 1983, *Fluid Mechanics*, University of Michigan.

Maier K. H., 1991.,*Energie-Optimierung von Anlagen in der Industrie*, Frankfurt/M, Rationeller Energieeinsatz bei Degussa,

(Journal article)

Ćirić S. & Pešić N.,1982, *Projektovanje daljinskog grejanja sa predizolovanim cevovodima*, Beograd, Naučno-stručni časopis KGH, Broj 1/1982.

(Symposium procedings)

Miletić M.,1986, *Optimizacija transporta toplotne energije iz TE-TO Kolubara B primjenom računara*, VII savjetovanje o energiji u Opatiji.

Zavod za projektovanje i inženjering "Janko Lisjak"-Beograd 1980, *Toplifikacija Tuzle*, Uvodni projekat. (Project)

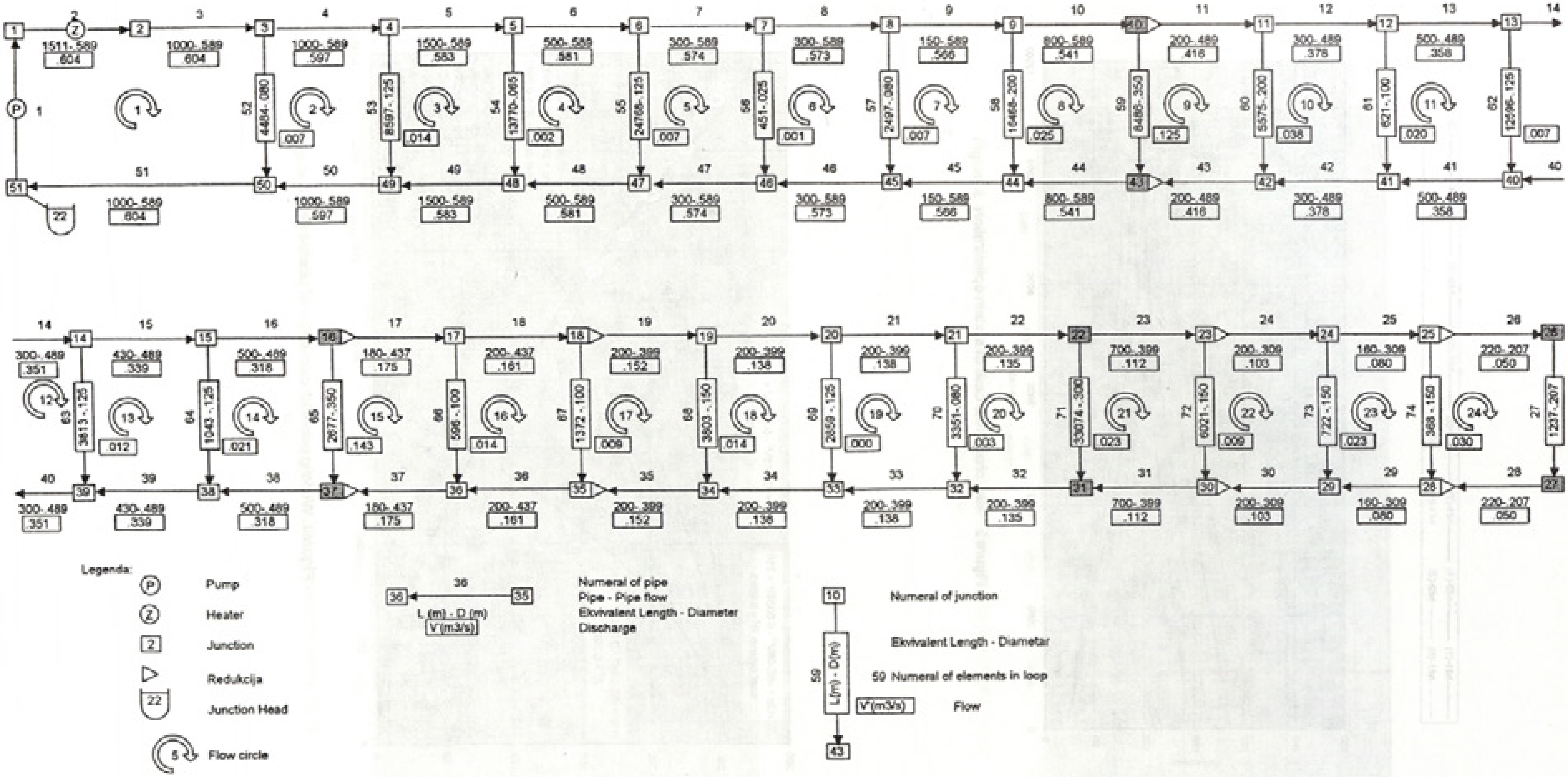

Figure 1. Scheme of the pipeline model for long-distance heating system of Tuzla town

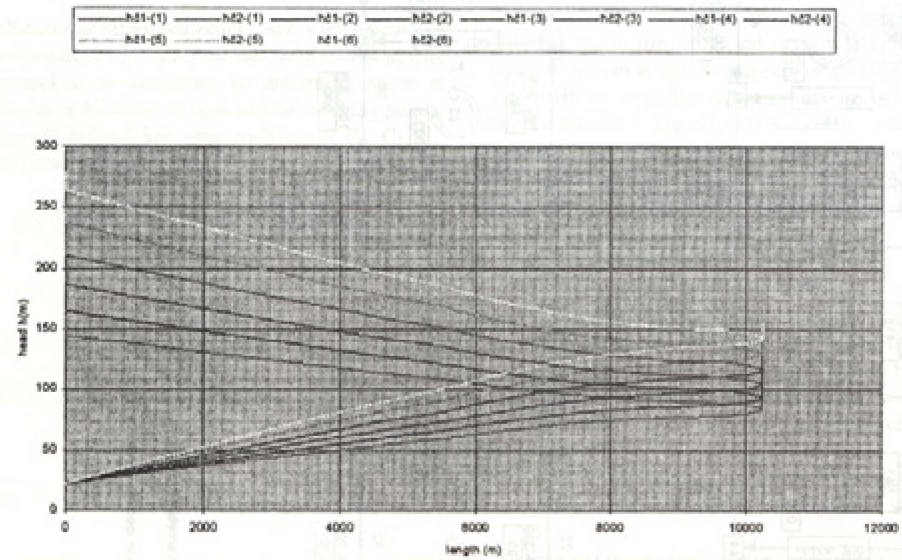

Figure 2 Head chart in the case of system optimization

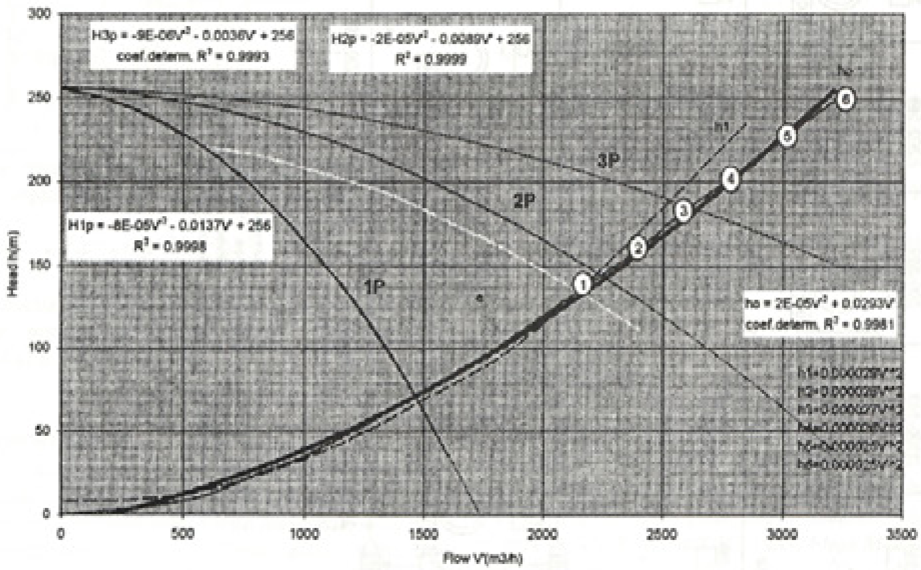

Figure3. Working points for calculation of pipeline net

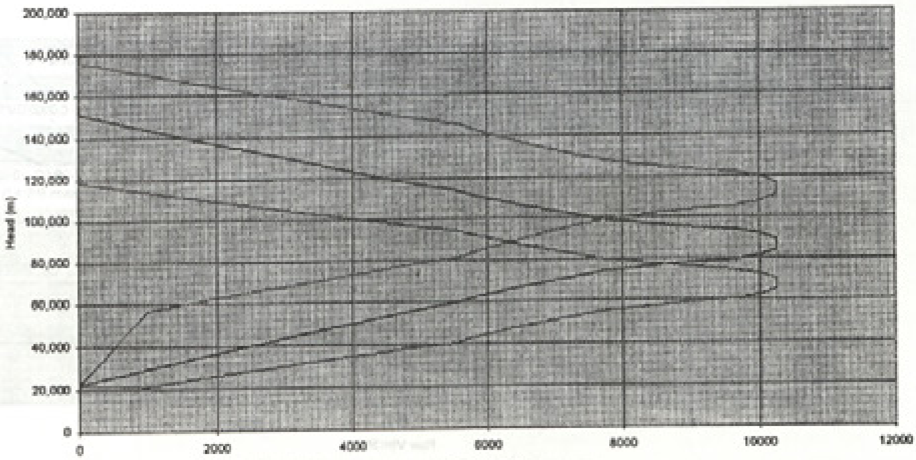

Figure 4. Head chart in the case of system optimization when user No. 59 ("Slatina") is cut off(446m3/h,35MW)

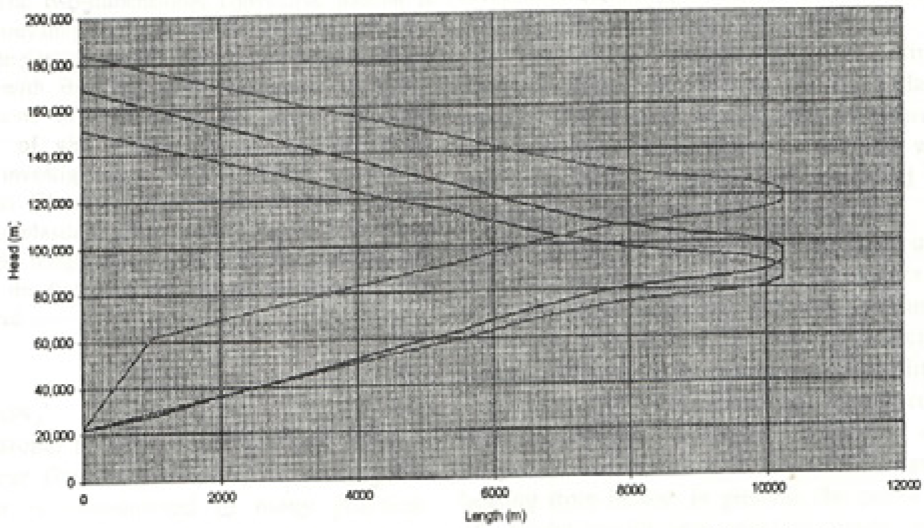

Figure 5. Head chart in the case of system optimization when increase of loading for all users

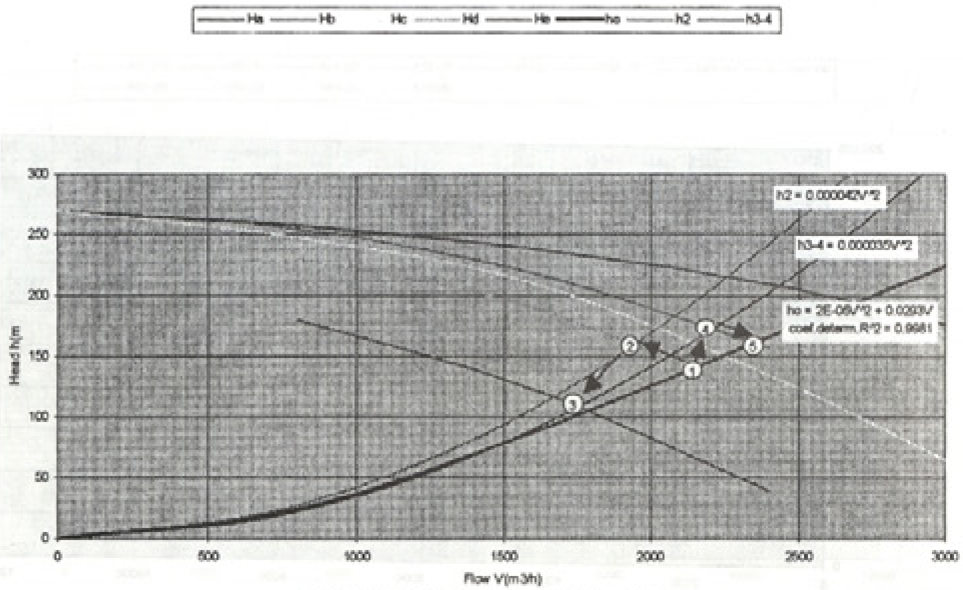

Figure 6 Defining of optimum working point
-- when user No. 59 ("Slatina") is cut off (1-2-3), -increase head pressure (1-4-5);
Ha,b,c,d,e -pumps characteristic, hi -pipeline characteristic