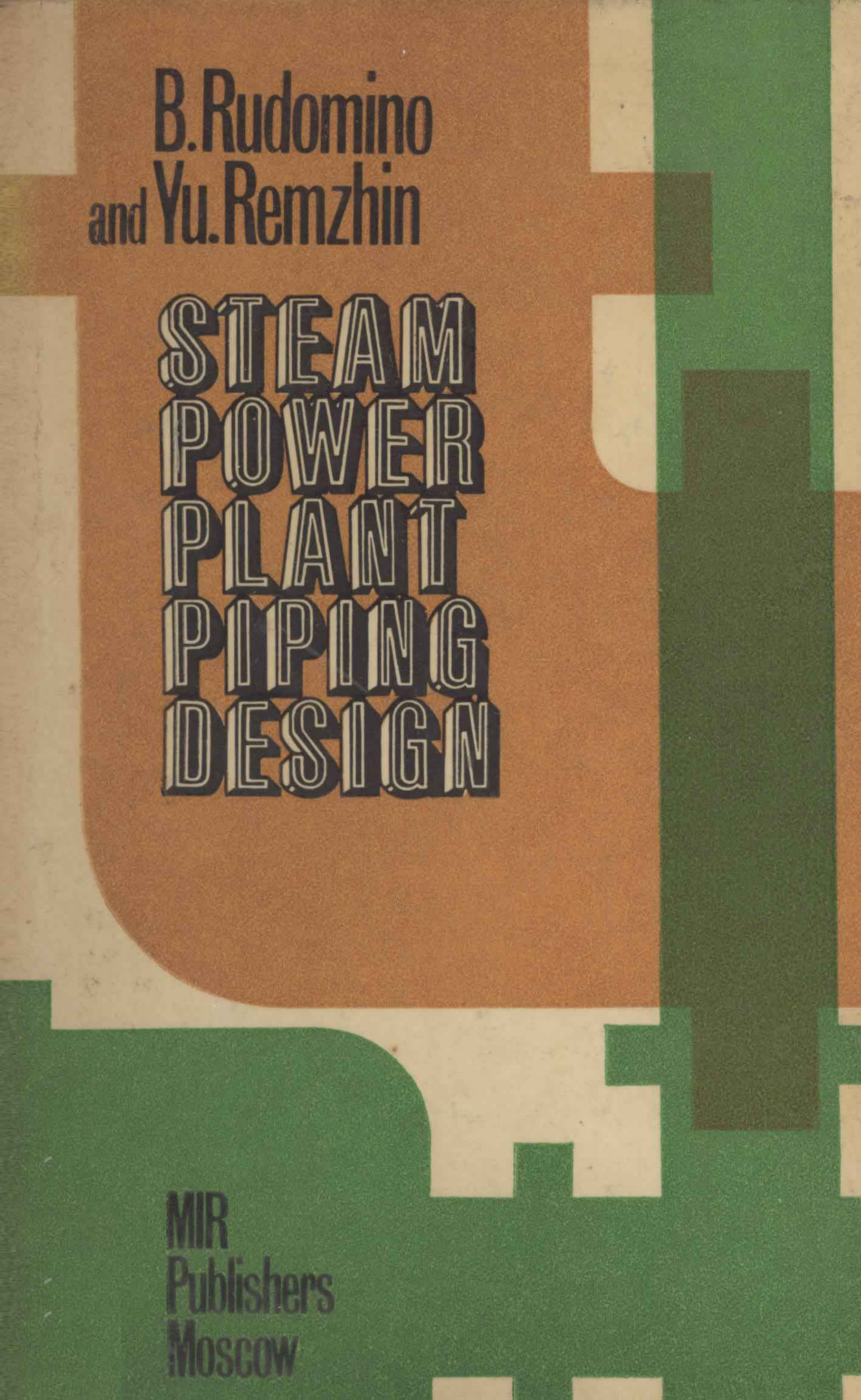

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STEAM POWER PLANT PIPING DESIGN

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ПРОЕКТИРОВАНИЕ ТРУБОПРОВОДОВ ТЕПЛОВЫХ ЭЛЕКТРОСТАНЦИЙ

«ЭНЕРГИЯ»
Ленинградское
отделение


ИЗДАТЕЛЬСТВО
МИР

B. Rudomino
and Yu. Remzhin

STEAM POWER PLANT PIPING DESIGN

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The Russian Alphabet and Transliteration

А а	a	К к	k	Х х	kh
Б б	b	Л л	l	Ц ц	ts
В в	v	М м	m	Ч ч	ch
Г г	g	Н н	n	Ш ш	sh
Д д	d	О о	o	Щ щ	shch
Е е	e	П п	p	Ъ ъ	”
Ё ё	e	Р р	r	Ы ы	y
Ж ж	zh	С с	s	Ь ь	’
З з	z	Т т	t	Э э	e
И и	i	У у	u	Ю ю	yu
Й й	y	Ф ф	f	Я я	ya

The Greek Alphabet

Α α	Alpha	Ι ι	Iota	Ρ ρ	Rho
Β β	Beta	Κ ϰ	Kappa	Σ σ	Sigma
Γ γ	Gamma	Λ λ	Lambda	Τ τ	Tau
Δ δ	Delta	Μ μ	Mu	Υ ϑ	Upsilon
Ε ε	Epsilon	Ν ν	Nu	Φ φ	Phi
Ζ ζ	Zeta	Ξ ξ	Xi	Χ χ	Chi
Η η	Eta	Ο ο	Omicron	Ψ ψ	Psi
Θ θ	Theta	Π π	Pi	Ω ω	Omega

На английском языке

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Chapter Four
Pipeline Thermal Elongation Compensation and Its Calculation

Foreword

During the last decade Soviet heat-power engineering has progressed significantly not only in increasing the total and unit capacities of power plants, but also in improving the thermodynamic cycle by using intermediate superheating and raising the initial parameters of the heat cycle. Concurrent with this, the piping layouts have also changed: on the one hand, they have become simpler owing to the change-over to unit systems, but, on the other hand, more complicated because of the use of superheating. The increased steam parameters have required the use of new grades of steel with improved long-term strength at elevated temperatures and especially thick-walled pipes which, in turn, has made it necessary to improve the piping design methods.

Nowadays, strength calculations of pipelines should be made as stipulated by "The Standard Procedures to Calculate Steam Boiler Elements for Strength" [3-1]. Piping design accords with industrial branch standards (OCT) and interbranch standards (MBH) which cover piping elements, fastenings and remote control devices. These standards make it possible to manufacture piping elements on a mass scale despite the fact that the actual piping design work is carried out by different design bodies. They also eliminate the need to describe in detail the methods of calculating for strength various piping elements and fastenings, thus enabling one to restrict oneself to the general principles of strength calculations, the knowledge of which is essential for a piping designer.

The advent of digital computers has considerably improved the piping design. At present, calculations of self-compensating pipelines are made by using computers. Computers have influenced much the piping design, for they have made it possible to calculate complex piping systems with movable inflection points and several anchor points, whose application was previously avoided because of the difficulties in designing them.

Being a special subject computer calculation techniques and programming are outside the scope of this book.

Here we only outline the general theory of computer-aided design of self-compensating pipelines, the knowledge of which is essential for the piping design engineer. In addition, an approximate, simpler calculation procedure assuring adequate accuracy is described. It is suggested that in designing self-compensating pipelines, the deformations of bent ovalled elbows under the action of internal pressure be taken into account, for they may significantly affect the calculation results.

At present, wide application have found sharply bent thin-walled elbows which must be checked for the maximum stress variation range lest they should develop fatigue cracks. Methods for determining the stress variation ranges are described in this book and allowable values given.

A new method is proposed to calculate thermal expansion compensation for pipelines using bellows-type expansion joints as hinges. Along with hydrodynamic calculations for usual pressure drops, methods for calculating piping with large variations in specific volumes are discussed. These methods are necessary to select correctly the size of exhaust pipes and blow-off lines, to calculate the discharge rate of pipelines at large pressure drops, and to analyse the emergency operating conditions under which piping may have to work.

The section dealing with the choice of an economical piping size has been thoroughly revised in accordance with the present-day technical and economic calculation methods used in power engineering.

This book is mainly for engineers engaged in the design of thermal power stations. It may also be used as a textbook for students specializing in steam power plants.

The need for the present edition was long felt, as a book of similar content [3-12] was last published about 20 years ago.

Chapter One

Piping Layout and Design

1.1. Piping Project Design

Piping project design begins with the working out of a draft piping layout on the basis of a detailed heat flow diagram. Questions relating to the use of stand-by equipment (boilers, pumps, etc.) and pipelines to replace the units shut down for repairs are decided upon in the course of the piping layout elaboration. In the last 10-20 years the heat flow diagrams of power plants have become more complex because of the use of intermediate superheating, adoption of higher steam pressures and temperatures, increased unit capacities, improved regenerative cycles, inclusion of turbo-feed pumps in the main turbine cycle, etc.

At the same time the layouts of condensing steam power plants have been considerably simplified by dropping stand-by boilers and pipelines, and by equipping the plants with separate power units not interconnected through main lines.

A considerable improvement in piping reliability has been attained by avoiding flange joints and using flangeless fittings on high-pressure lines, and by improving welding processes and weld inspection methods. This has made it possible to use a single-line feed water piping, without any stand-by pipelines, even for box-header boilers. In modern practice multiline pipings are used only when a single pipeline of maximum size proves incapable of handling the required flow.

Figure 1.1 shows the main steam line layout of a K-200-130 unit in which provision is made for two lines of nominal size $D_n = 250$ mm for fresh steam and six lines of nominal size $D_n = 400$ mm for reheat steam (two lines to the boiler and four from the boiler to the turbine). Heating and power plants, especially those supplying steam for industrial

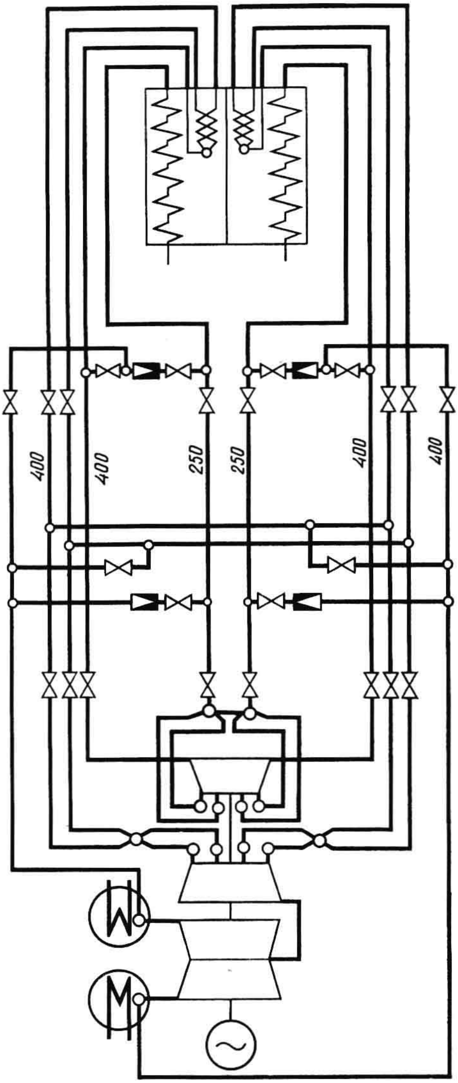

Fig. 1.1. Main steam line diagram of 200-MW unit

purposes, use stand-by boilers. In this case the main steam lines, feedwater lines and condensate lines are equipped with a crossover connection. Such a main steam line layout for a heating and power plant is shown in Fig. 1.2. On disconnecting the boiler-turbine steam lines from the crossover connection, the system changes to a unit-built type,

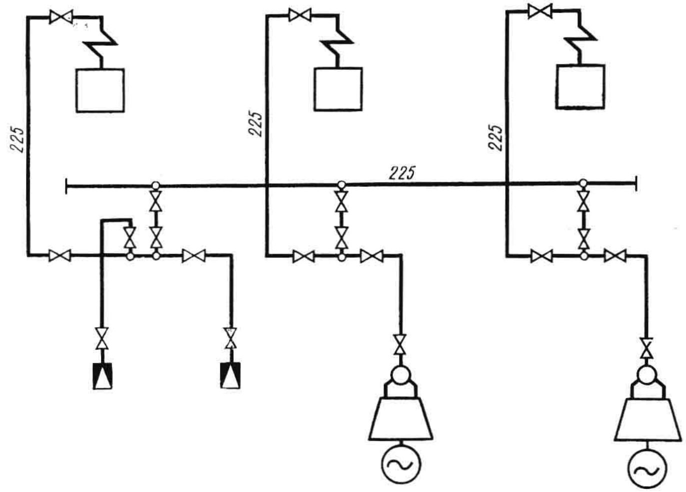

Fig. 1.2. Schematic of steam lines at heat-and-power unit with a cross connector

thus providing for the required redundancy and enabling one to repair the crossover connection. Other sections of the piping system are repaired at the same time as the equipment they serve. To ensure safety, the layout provides for not less than two stop valves to disconnect each piece of the equipment from the pressure lines in case of repair.

High-pressure (more than 22 kg/cm^2) and low-pressure pipings are designed separately. Such a division is dictated by the supply and erection conditions. The design is carried out in accordance with the OCT and MBH standards for the manufacture of the individual components and units of pipelines. The design high-pressure piping plan embraces fresh steam lines, reheat-steam lines, feedwater lines and auxiliary high-pressure pipelines. The low-pressure piping plan involves the following piping assemblies: extraction lines, including steam-supply lines for deaerators, and metered bleed lines; main condensate lines; station tank-system lines; chemically treated water lines; drainage discharge and overflow lines; circulating-water lines; cooling-water systems for bearings and mechanisms; lubrication lines; fuel-oil lines; fuel-gas lines; ash-sluicing systems; compressed air piping; hydrogen, oxygen and acetylene piping systems, and others.

Approximately 50% of the total design and planning work on the thermal and mechanical equipment of a power plant is taken up by the piping. The design and planning of a piping system includes the following stages: (1) working out of a rational piping schematic diagram which would ensure reliable operation of the equipment, its automatic control, starting and heating up; (2) selection of standardized pipe sizes on the basis of technical and economic calculations; (3) elaboration of the piping layout, selection of a thermal expansion compensation system and positioning of anchored and movable fastenings; (4) compilation of tasks for calculating self-compensating pipelines and spring fastening; (5) computer-aided calculations; (6) analysis of the computerized calculation results; (7) hydrodynamic calculations; (8) development of blow-off and drainage piping systems; (9) breaking down of the piping system into standard factory-supplied units and piping components, with allowances required for welding bosses and nozzles, preparation of working drawings for non-standard components; (10) design of fastenings; (11) design of thermal insulation.

If the calculation results for self-compensating pipelines prove unsatisfactory, the piping layout should be corrected and check calculations made on a computer. The working drawings of the high-pressure units are generally prepared by the manufacturer.

1.2. Layout and Design

The piping layout is predetermined mainly by the arrangement of equipment in the main power-plant building. The arrangement of the equipment, the coordinates of the connecting branch pipes and nozzles of power units and heat exchangers serve as the starting point for elaborating the piping layout versions. Lately, the tendency to select the most convenient and shortest routes for the most important lines has had an ever increasing bearing on the equipment arrangement in the main building. It applies, in particular, to the reheat-steam lines, as it is necessary to ensure a minimum pressure drop in them, and to the main steam lines, because their cost is high. That is why turbines are located with their axes across the machine hall as this reduces the length of the main steam lines compared to the lengths required if the axes were placed longitudinally.

The unit boiler-turbine systems are essential for high-capacity power units with intermediate superheating. The elimination of cross connections between the unit boiler-turbine systems has simplified the piping layout diagrams and alleviated layout problems. At the same time other difficulties arose due to the necessity of routing a large number of boiler-to-turbine steam lines (main and intermediate superheat). For routing boiler-to-turbine pipelines of a 300 MW unit a frontal width of 24 metres is necessary.

At heating and power plants using cross connections a special corridor is provided at the hopper-deaerator level for cross-connection pipelines (main steam cross-over valves, feed-water valves and others) and cross connectors to be mounted. Generally the turbo-sets are arranged longitudinally in the main machine hall. This arrangement provides better compensation of pipelines between the fixed anchor points in the corridor up to the turbine stop valve. Of late, recourse is taken to transverse location of turbo-sets as it is more convenient for the main hall layout.

In general, it should be noted that in a well arranged main hall layout due consideration is always paid to the convenient routing of most important pipelines. This, in particular, applies to the location of feed pumps, economizers, deaerators. Before making a piping layout the economical pipe diameters should be determined. In some cases, final selection of pipe diameters is possible only after the piping route is selected which determines the overall hydrodynamic resistance coefficient for the piping system being designed. In the further examination of layout problems we shall assume the pipe diameter as determined. When developing the piping layout the pipeline routes are indicated with the thermal expansion compensatory methods, location and types of anchors location of fittings, type and location of drives for accessories, slopes of pipes, condensate and air removal points, drainage system, positions and dimensions of service platforms.

A well thoughtover layout should ensure: easy erection, possibly using large units; convenient servicing and repair; good thermal expansion compensation; minimum hydraulic resistance; minimum weight; simple and convenient fastenings; good drainage; accessories of the same type; absence of cast elbows and non-standard components; possibility of plant expansion without piping modification with a minimum shutdown time of earlier installed units for connecting reassembled piping systems.

In certain cases it is difficult to fulfil all the requirements and the task of a piping designer is to find optimum solutions which would satisfy to the maximum extent all given requirements. The modern unit power plants considerably ease the problem. We shall discuss in detail some of the above mentioned requirements.

Primarily, the following operations should be borne in mind, such as: heating, connection and disconnection of pipes, inspection of fittings and maintenance of its packing glands. The fittings should be located at places readily accessible for operation, review, maintenance and repair. The most preferable location of the equipment is on the main working floors of the building.

In case the equipment is located at places inaccessible for direct maintenance from the working levels, then remote controls should be provided for operators at convenient places. Platforms should be designed for inspection and repair of such equipment. Devices for hanging pulley blocks should be provided over the location of heavy equipment.

Steam pipelines at 450°C and above require periodic checking for metal creep rate, condition of welded seams and should be laid at places where their diameters can be easily measured. The main routes of such pipelines should be located at ceiling floors of the building. Service platforms should be provided for the sections of high temperature pipes running at high levels (for example, section from the steam gate valve of the boiler up to the columns of the boiler house).

The pipeline route and the location of rigid anchors should be sufficiently flexible so that self-compensation stresses, forces and moments transmitted by the pipelines to the equipment do not exceed permissible values.

First of all the intrinsic flexibility of a pipe should be used when laying it along its actual path. The flexibility of a pipeline may be increased by artificially lengthening shoulders, by providing additional bends or by cutting in U-shaped expansion joints but only when sufficient thermal expansion compensation is not achieved by placing rigid anchors in the most rational way or by discarding superfluous supports along its actual path. It should be borne in mind that artificial lengthening of a pipeline entails an increase in pipeline's weight and pressure losses.

A simple method to increase the flexibility of a pipeline route and to decrease the forces and moments transmitted to the rigid anchors is to avoid the excessive use of rigid anchors. Objections to such a decision could be: increased pipeline displacements and the consequent difficulties with spring suspensions and increased tendency of a pipeline to vibrate. In such cases different variants of anchors, which limit displacement in one or the other direction, should be examined.

For low pressure pipelines temperature compensation may be achieved by the use of bellows-type expansion joints. These compensators are very effective in hinged diagrams.

The following must be observed to achieve minimum hydrodynamic losses in a pipeline of a given diameter: (a) avoid superfluous bends; use a straight track so that track length and bend angles may be reduced (Fig. 1.3*a*); (b) install tee joints so that the main stream passes straight through the joint (Fig. 1.3*b*); (c) do not use valves of constricting diameter as they have a high resistance coefficient. If such valves are used, straight runs of pipes are necessary before and after the valve (distance of 10-12 diameters before and of 5 diameters after the valve) to avoid abrupt increases of hydrodynamic losses in excess of the value accounted for by the valve resistance coefficient; (d) for high flow rates in pump pressure pipings (up to 5-7 m/sec) a large diameter reducer should be installed immediately after the piping and then a return valve and a gate valve (Fig. 1.3*c*); (e) do not use tee joints as alternatives to elbows, as is sometimes done, when it is necessary to have a rigid anchor close to the bend; (f) when branching a pipe into two pipes of smaller diameter the tee joint size should be assumed equal to the diameter of the supply line.

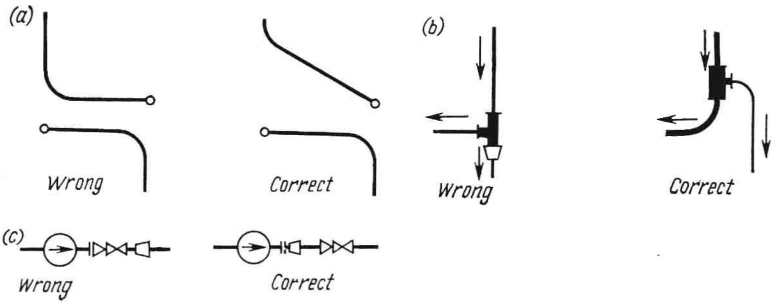

Fig. 1.3. Selection of bends and tees with the aim of reducing hydrodynamic losses

To anchor conveniently pipelines, their routes should be positioned close to columns, along ceiling floors and gangways. While laying small diameter pipelines having permissible spans less than the column spacing special anchor structures should be provided between the columns. When constructing building frameworks the precast reinforced concrete units should contain metallic insertions to which the pipeline supports may be welded.

The routes of pipelines should be so selected as to avoid excessive upper and lower points which would require special drainage devices and air vents. The slopes of pipelines should be selected along the direction of steam flow with due regard to the increase in deflection sag due to metal creep.

While designing pipings it is necessary to strive for the use of similar type of pipeline units as it reduces the number of drawings, calculations, and simplifies the design and