Optimization of heat carrier distribution system in thermal power stations

Ioan Sarbu and Doru Pelivan

***Abstract*—** The present paper is a summary developed from the author's studies, conducted over a period of many years and throughout the design, implementation, commissioning and servicing hot water boiler rooms, with temperature not exceeding 115 °C. This paper relates to study the advantages and disadvantages of the principal, systems and modes of distribution of heat carrier, desig-ned according to the most used thermo hydraulic schemes of hot water boiler rooms with power over 100 kW. To eliminate these disadvantages, the authors propose a new distribution system apparently similar to those existing, but actually different, by its advantages. The main component of the proposed system is a "different" flow/return manifold of the heating carrier, called "monoblock flow/return manifold with separating diaphragm".

***Keywords*—** Flow/return manifold, Heat boiler room, Monoblock manifold with separating diaphragm, Pressure equalizing tank.

I. Introduction

In the past 100 years for heating different spaces in buildings to be used as a heat carrier, hot water, produced at different temperatures and pressures.

According to norms, the concept of "hot water" as heat carrier refers to water with temperature that does not exceed 115 °C.

Technical spaces in which is installed the equipment that produces heat, are known as thermal power stations (hot water boiler rooms).

The best known generators that produce the heat carrier (heating the hot water) are hot water boilers. They can be classified using several criteria:

– the nature of fuel used (gaseous, liquid, solid, biomass);
– temperature of the produced agent (high, low, normal/in condensation);
– the material from which the iron cast is built (steel, iron).

In recent years, advances and innovations in the concepts of thermal energy production, have led to the development of many new equipment: solar systems, heat pumps, cogeneration groups.

However, due to limits of performance of new equipment, boilers continue to be basic generators for producing hot water, used as heat carrier, cohabitating under various thermo-hydraulic schemes with the new systems.

According to norms and literature facilities, boiler rooms are classified by the hot water boilers installed in [6]:

– low (up to 100 kW);
– medium (100…2000 kW);
– high (over 2000 kW).

For maximum powers of 100 kW exist in the field, a wealth of equipments, automate systems, specialized litera-ture (the majority is written and provided by the manu-facturers).

At the present moment large–sized constructions are designed and built and for satisfying the heating requirements there are necessary medium and high hot water boiler rooms (over 100 kW).

New buildings contain more and more areas with different functions: housing; offices; commercial spaces; restaurants; storage spaces; garages; production areas that require different ambiental temperatures, or various programs for operating.

Also, different heating systems are used:

– with radiators;
– with radiant floors, ceilings, walls;
– by ventilation;
– combined with other systems (solar, heat pumps etc.).

Currently many existing buildings are rehabilitated, consolidated or extended with new functions, job that extends to adapting installations, which often is a true "challenge" for the specialists in the field.

Unfortunately recent progress has concentrated on improving systems that produce heat (boilers) and the development of new systems (solar, heat pumps, cogeneration groups).

However, studies and progress concerning heat carrier distribution from the boiler room to different consumer groups had been negligible.

This paper is addressed to specialists in that field (designers, performers, manufacturers), and pleads for the use of the distribution system of heat carrier in hot water boilers with installed power over 100 kW, through a metallic con-fection called "monoblock flow/return manifold with sepa-rating diaphragm".

II. Mostly Used Schemes for Heat Carrier Distribution

It is true that the existing literature is not sufficiently generous with theoretical and practical data on explaining the advantages and disadvantages of using various principial thermo hydraulic schemes used for building a high power

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boiler room. There are several basic schemes, developed by various specialists, variations being based on and referring to different automation equipments designed by the manufacturers.

It has been concluded that designers and executants assume these principial schemes found in the technical catalogues and use them inertness without taking into consideration the needs, the advantages and disadvantages resulting from using them, correlated to concrete situations.

From the authors experience in the fields of design, execution, implementation and servicing the hot water boilers rooms, it was concluded that unfortunately designers in the field do not know basic theoretical concepts in terms of sizing, advantages and disadvantages of various heating equipments, such as: manifolds, pressure equalizing tank, expansion vessels etc. For these reasons, the beneficiaries have to support high costs, both initial (higher costs of investment) and subsequently (operating costs, maintenance, repair).

After a period of using the installation beneficiaries realize that the ratio between the cost for investment plus operation and the effects is not efficient, that the additional costs needed for rehabiliation and modernization would be very high and that the performance rating would not be satisfying.

For attaining a hot water boilers rooms with medium and high power and with an efficient and easy operation on every aspects, choosing the principial thermo hydraulic scheme and heat carrier distributing manner is the most important aspect and should be taken into consideration by the designer, the executants and the beneficiary.

For distributing the heat carrier to consumers it is used a metallic confection called “flow manifold”, which consists in a steel pipe section, closed at the ends by two deeps, made from thick steel plate, that are straight or bombed (depending on the pressure at which it is used) [3], [17].

The flow manifold shall be fitted with welded black stub ends, open ends being threaded ends or fitted with flanges, with the following destinations:

– ingoing of flow pipe from the boilers;

– outgoing of flow pipes to consumers or consumer groups;

– emptyings;

– connection of control devices (thermometers, manometers etc.).

The "return manifold" is equipped similar to the flow manifold [3], [17] with connections having the following functions:

– outgoing of the main return pipe to the boilers;

– ingoing of return pipes back from consumers or con-sumer groups;

– emptyings;

– connection of control devices.

Flow and return manifolds are dimensioned so that available pressures are equal at the flow connections, which implies that frictions in this metallic confections should be as low as possible. In practice it is considered that the movement velocity of water through them should be below 0.5 m/s [6]. Lengths are chosen to allow the usage of the valves’ operating handles.

In Fig. 1 is given a principial scheme of a hot water boiler’s room, in which the circulation of the heat carrier is achieved using common pumps to all consumers, positioned upstream of the manifolds. This distribution type presents major disadvantages:

– impossibility of efficient control over the flow that goes to consumers, making the adjust-ment manual;

– unable to supply quality heat (different tem-peratures) to consumers;

– presence of the operating staff, needed to manually operate valves.

This thermo hydraulic scheme is used nowadays very rarely.

Fig. 2 represents principial scheme of a hot water boiler room which eliminates the disadvantages of the distribution in Fig. 1, and allows:

– heat carrier delivery to consumers, with needed individual flows, supplying pipes being equipped with individual pumps sized adequate;

– quality delivering of supply lines (variable temperature), depending on the consumers’ needs, by using motorized three way valves and adequate command / automate panels.

Because of the sitting of the manifolds, one next to the other, this scheme raises special problems in execution due to the necessity of achieving bypass pipes between the three way valves, situated on flow and their pairs, the return pipes. It requires additional quantities of pipe and fittings. The aesthetics of this mode of distribution is always unsatisfying.

To eliminate disadvantages of the distribution in Fig. 2, in practice it is used a similar scheme, presented in Fig. 3. The difference consists in the sitting of the manifolds. They are no longer attached, but located superimposed and with a decalage between them.

Compared to the scheme in Fig. 2, it is made a great saving of materials. The disadvantages consist of:

– difficult and more laborious execution;

– troublesome way of utilization and assistance for repair, because of the ensemble’s “depth” in space.

All the schemes presented in Fig. 1, 2 and 3 have othe major disadvantages:

– regardless of the fineness of execution, the aesthetic of the pipe distribution in the boiler room is not satisfactory on account of the manner in which the executants can set up the pipes’ routes;

– costs of investment and operating costs (electricity) are higher due to the need to provide more powerful pumps to overcome additional friction generated by the local distribution resistances (elbows, derivates etc.), therefore the pumps are chosen, often for covering, unjustified bigger regarding the pumping heights, of course without proper hydraulic calculation. In this case, the pumping flow changes, in comparison to the needed ones, and creates turbulences in the manifolds and valves, so that they don’t fit the original sizing [7].

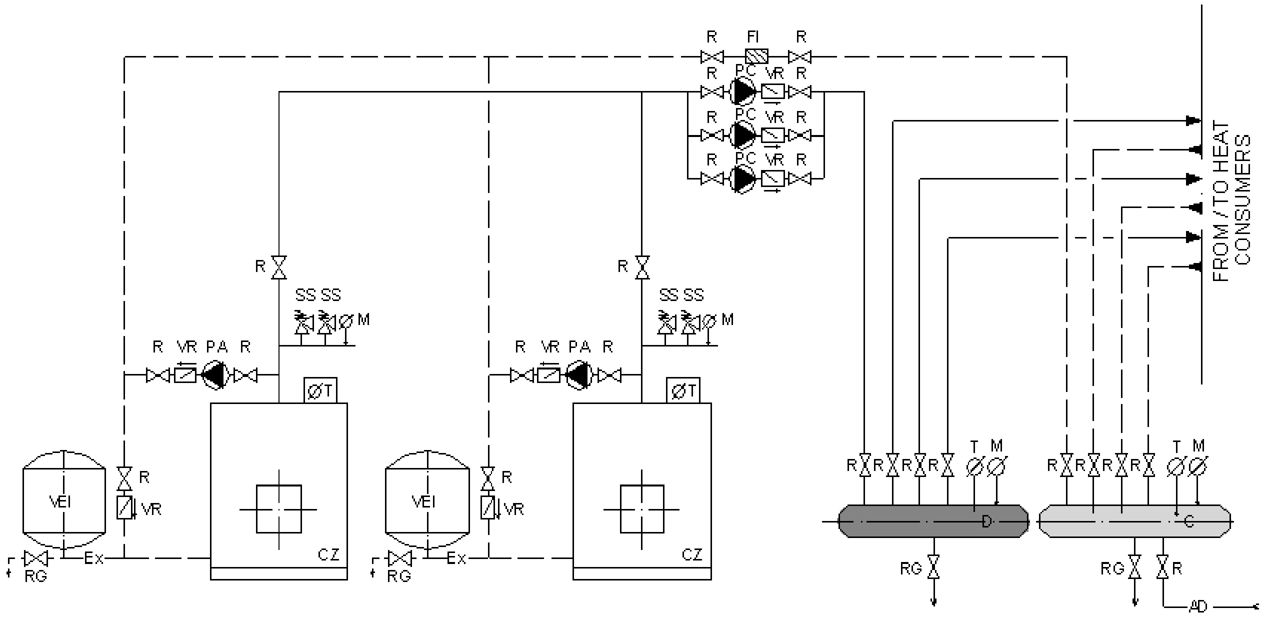

Fig. 1 Scheme of heat carrier distribution in a hot water boiler room, through adjacent and separated flow and return manifolds, with individual circuits for every consumer group (heat carrier circulation through common pumps)

CZ-hot water boiler unit; VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D-flow manifold; C-return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer;

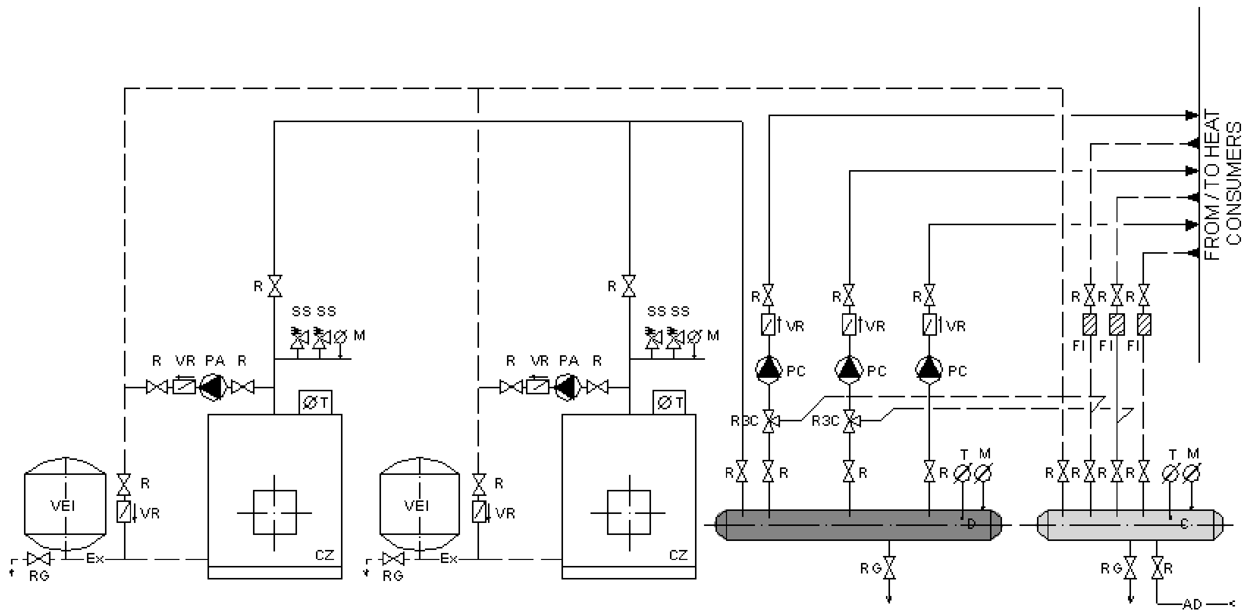

Fig. 2 Scheme of heat carrier distribution in a hot water boiler room, through adjacent and separated flow and return manifolds, with individual circuits for every consumer group (heat carrier circulation through individual pumps)

CZ-hot water boiler unit; VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D-flow manifold; C-return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer;

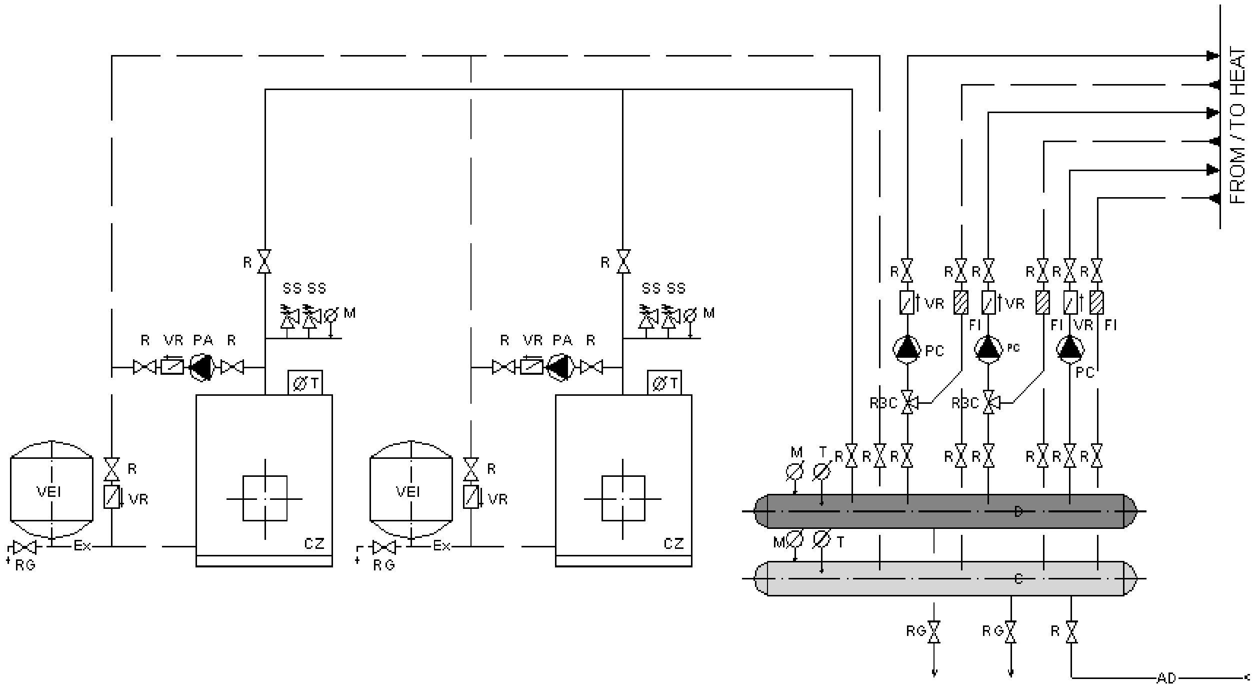

Fig. 3 Scheme of heat carrier distribution in a hot water boiler room, through superimposed and separated flow and return manifolds, with individual circuits for every consumer group (heat carrier circulation through individual pumps)
CZ-hot water boiler unit; VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D-flow manifold; C-return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer;

These inconveniences have consequences for the beneficiary: the electricity costs rise unduly, consumers are no longer properly supplied as flows and temperatures, provided automation systems become useless, regardless of the cost of their investment.

In the case of distribution systems with a large number of groups of consumers, which requires the use of pumps with distinct flow/pressure characteristics, it is necessary to interpose between the boilers and manifolds, a metallic confection, called pressure equalizing (bursting, mixing etc) tank, symbolized as the "origin" of the ensemble of pipes.

Choosing not to use the pressure equalizing tank leads to other disadvantages in the heat carrier distribution:

– in the manifolds, appear some remaining pressure differences, positive or negative, on various “arrivals/departures”;

– turbulences occurring in flow manifolds create problems of aspiration to pumps;

– pumps are influencing each other, the large ones "leave without water”, the small ones, which will crash;

– the three way valves function defectively, no matter what automation is provided and the temperature qualitative adjustment is not proper;

– maximum differential pressures upstream/ downstream of the three way valves are impossible to be controlled and they become unduly elected; the effect is the alteration of the outgoing flows, in comparison to the ones estimated, so that the consumer’s appropriate ambient temperature is impos-sible to be achieved. Therefore, consumers that should not be supplied in some periods will receive heat;

– effects of the mixing and adjustment valves’ malfunctioning, result in additional and unjustified heat loss, on the pipe routes to consumers;

– turbulences created in the manifolds and valves cause all sorts of noises, which are transmitted by pipeline, and are claimed by the occupants of the buildings;

– unduly increased operating expenses related to electrical energy and fuel used;

– costs of improvements that can be made to diminish the effects presented (for example using pumps with variable hydraulic characteristics) are not effective because the results are minimal.

III. Proposed Schemes for Heat Carrier Distribution

In the investigations and documentation performed new principles and solutions were searched in order to obtain other ways of heat carrier distribution to consumers, solutions that should be trustworthy and applicable for hot water boiler rooms schemes, exceeding 100 kW.

The most important criteria, which were taken into account during the research that was completed in recent years and in the analysis of some special hot water boiler rooms, were:

– removal, as much as possible, of all the disadvantages of mostly used scheme for heat carrier distribution;

– “what must be done” for such a technical area to have a distinctive aesthetic of the installations, to be easily achieved, used and serviced even by unskilled staff, at the highest efficiency.

It is concluded that everything is achievable if it is found a new concept for executing the heat carrier flow/return manifolds.

After the study was made and taking into consideration the criteria mentioned above, there were found only two trustworthy concepts, which solve the above conditions. These two concepts of flow/ return manifolds, completely dissimilar, concerning the theoretical fundaments and construction, are produced by two German manufacturers Magra Maile & Grammer GmbH and Zortea GmbH [16], [19].

The authors have tried to develop a new concept in constructing the flow/return manifold, the concept being already applied over the past 20 years in the design and execution of numerous hot water boiler rooms exceeding 100 kW.

Fig. 4 presents the concept of this metallic confection, called "monoblock flow/return manifold with separating diaphragm". Circulation pumps are similar flow/pressure characteristics.

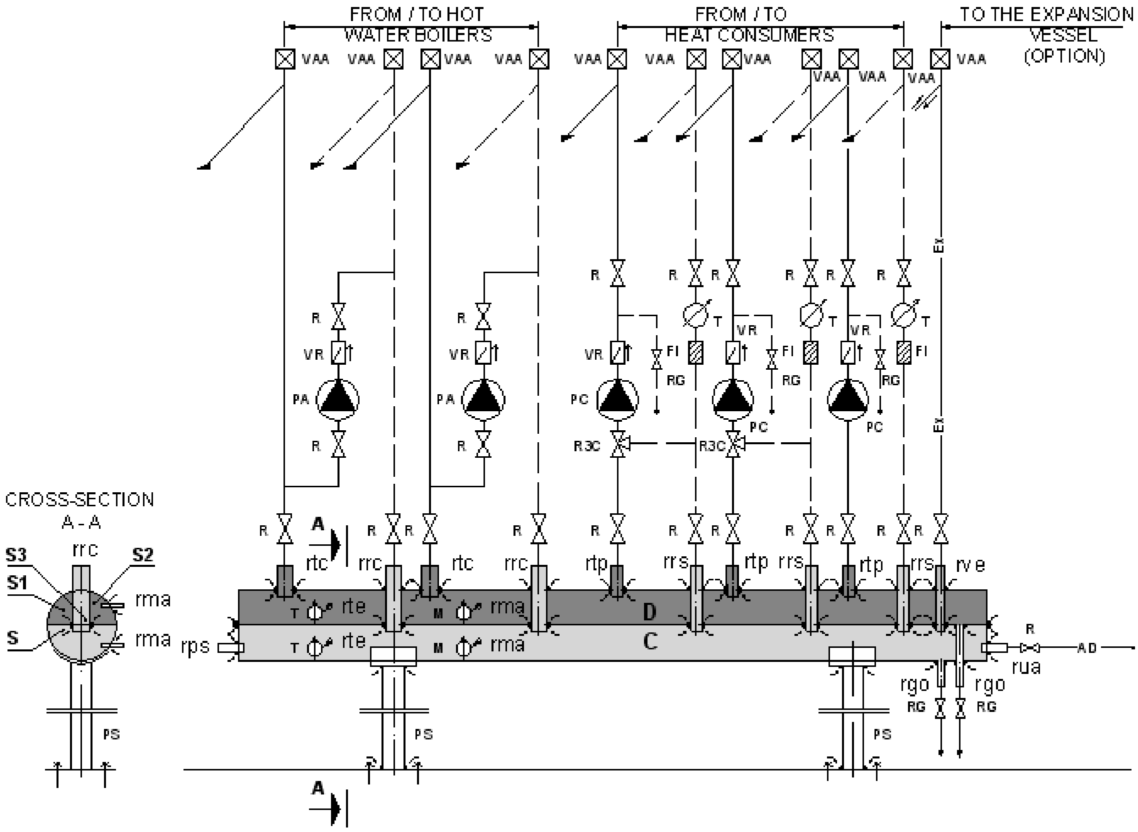

Fig. 4 Scheme of heat carrier distribution in a hot water boiler room, through a monoblock flow/return manifold with separating diaphragm

CZ-hot water boiler unit; VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D, C-monoblock flow/return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer; Black stub ends: rtc-flow from the boiler; rrc-return to boiler; rtp-outgoing flow to consumer; rrs-ingoing return from the consumer; rve-expansion vessel; rua-filling/addition; rgo-drain; ma-manometer; rte-thermometer; rps-water lack pressostat

The construction consists in a bicameral (two compartments) metallic piece, the upper volume (compartment) representing the flow manifold and the lower one being the return manifold. In the upper section the flow is carried ("ingoing" from the boilers and "outgoing" to the con-sumers). In the lower section the return is carried ("ingoing" from the consumers and "outgoing" to the boilers). The com-partments are tight separated by a diaphragm made of steel plate. To make possible the future distribution, the manifold has welded connections so that mixing the flow and return would be impossible. The success of this manifold is assured by the "paired" connections (for flow and return) for a spe-cific destination.The flow manifold has the same sizing requirements as the classic ones, the speed of the hot water in internal cross–section to be under 0.5 m/s [6].

The differences in construction between the manifolds provided by Magra Company and the ones suggested by the author consist in the metallic profiles used. For producing this confections, Magra uses channel bars ("U"–type profiles) made of steel plate and manufactured in the own factory, specific for the given conditions. The manufacturer's technology allows it to produce "U"–type products with the same width, but different heights for the flow and return manifold [10].

The authors propose another solution: producing of the manifolds of steel pipe, available on the market (laminated at high temperature SR 404 or helical welded SR 6898), divided with the cut generator. This solution has been chosen for economical reasons (to diminish the costs) and to be widely applicable.

The diameter of the pipe used results from the requirement for the speed of hot water through the internal cross–section of the flow manifold. The return manifold will have, by construction, the same height (radius) as the flow manifold. The length of the confection is determined so that operating the handles would be easy and according to the size of the valves that equip the "ingoing and outgoing" pipelines.

The monoblock manifold with separating diaphragm can be used for heat carrier distribution:

– alone, when the consumers need flows and disposables with relatively equal pressures (Fig. 4);

– connected with a pressure equalizing (bursting, mixing) tank when the groups of consumers need flows and pressures completely different (Fig. 5); circulation pumps are distinct flow/pressure characteristics.

Principial scheme of a complex hot water boilers' room, with one or several boilers that supplies an assembly composed of many groups of consumers, with different needs, and with the ability to eliminate all the disadvantages of classical modes of distribution is presented in Fig. 6.

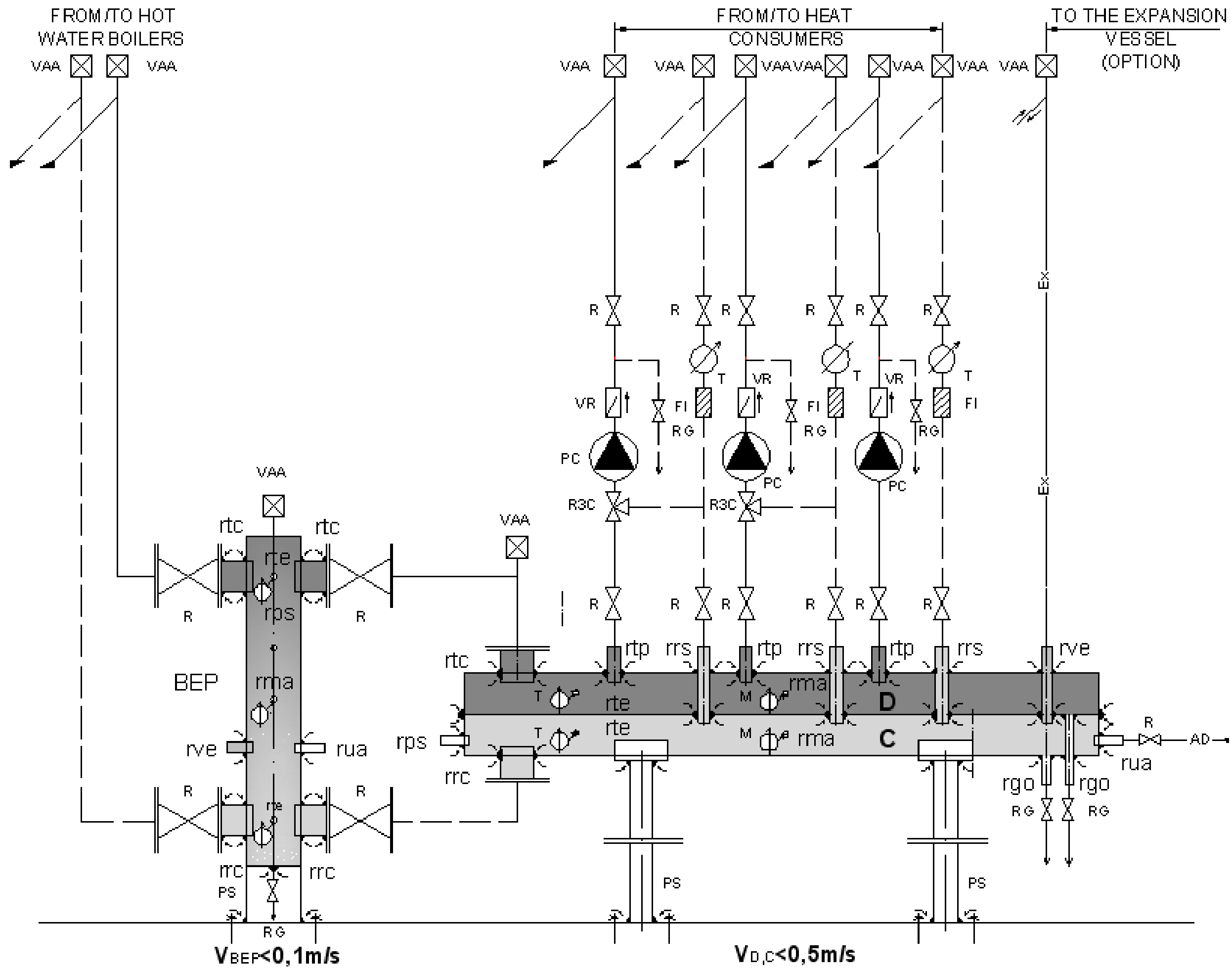

Fig. 5 Scheme of heat carrier distribution in a hot water boiler room, through a monoblock flow/return manifold with separating diaphragm, connected with a pressure equalizing tank

CZ-hot water boiler unit (max. 115 °C); VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D, C-monoblock flow/return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer; Black stub ends: rtc-flow from the boiler; rrc-return to boiler; rtp-outgoing flow to consumer; rrs-ingoing return from the consumer; rve-expansion vessel; rua-filling/ addition; rgo-drain; ma-manometer; rte-thermometer; rps-water lack pressostat

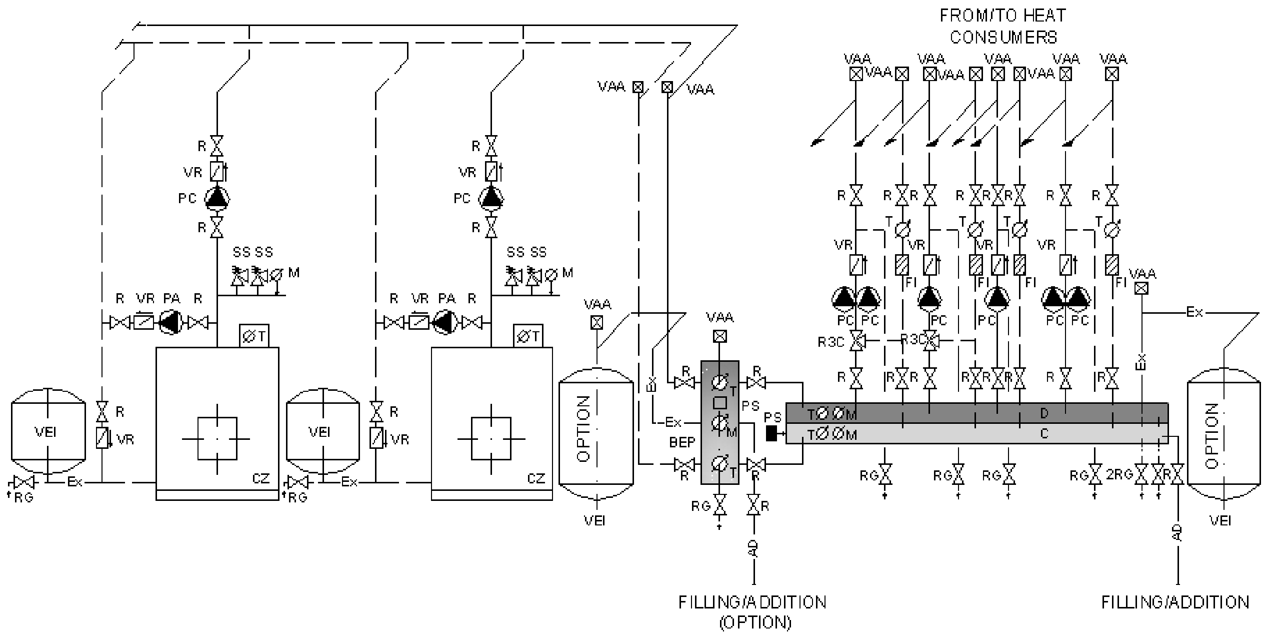

Fig. 6 Scheme of heat carrier circulation through individual pumps, for every consumer (individual circuits for every consumer group)
CZ-hot water boiler unit (max. 115 °C); VEI-expansion vessel; PC-circulation pump; PA-mixing pump; D, C-monoblock flow/return manifold; BEP-pressure equalizing tank (pressure bursting cylinder); PS-bracket; R-stop valve; RG-drain cock; R3C-motorized 3-way valve; VR-check valve; VAA-automatic air vent; SS-safety valve; M-manometer; T-thermometer; PS-water lack pressostat

The thermohydraulic scheme explains the way in which the heat carrier is distributed through the monoblock manifold with separating diaphragm, necessarily connected to a pressure equalizing tank (the "origin" of the system).

IV. Results and Discussion

Following the analysis performed after several years of operation of hot water boilers' rooms, in which the distribution of heat carrier is realised through the monoblock manifold with separating diaphragm mounted individually or coupled with a pressure equalizing tank, it has been found that all the disadvantages of the classical schemes were eliminated.

The advantages of using the new proposed concept are summarized below:

– boilers' rooms will have a high degree of isometric aesthetic, all the routes of pipelines may be ordered and supervised even by unskilled staff;

– all ingoing and outgoing of pipelines, to or from consumers, will be ordered in pairs: flow/return;

– pipelines situated horizontally will occupy maximum two vertical levels, expelling all the "pipe jams";

– the manifold will be the core of the boilers' room, allowing uniform and orderly setting, on the flow pipelines, of all the necessary equipment (valves, check valves, auto-matic air vents, automatic pumps, filters, mixing valves, ther-mostat ventiles, control manometers/thermometers, tempe-rature or pressure sensors from the automation system, etc.); it is also possible to connect other options: expansion vessels, automat filling/addition system etc.);

– in case of connecting the filling/addition system to the return manifold, the problem of thermal shocks with devastating effect in breaking the iron cast is eliminated;

– even if there are not connected the mixing pumps, pumps that protect against the thermal shocks, acid condense from the smoke pipes of the steel boilers or too cold returns from the consumers, the generators are protected due to the pre-heating of the return in the manifold, through the heat transfer made by the diaphragm from the flow manifold [9];

– elimination of all the turbulences in the manifold and valves on the flow pipeline allows proper operating of pumps and systems that assure quality temperature adjustment [4], [8];

– elimination of remaining pressure differences, positive or negative that leads to suppressing the pump mutual influence and also the deficient operating of the mixing valves;

– possibility to connect an unlimited number of consumer groups with different needs of temperature and also different operating schedules due to the perfect control of the flows and temperatures, according to the designer's wish;

– easy implementation and interventions for repairs;

– decreasing the initial investment by material savings and shortening the time of execution;

– complete elimination of permanently operating personnel or the need of superskilled staff;

– quiet functioning because the causes that generate noises are suppressed;

– increased equipment's length of life;

– decreased undue heat losses on the routes of pipelines to consumers;

– decreased operating expenses by at least 30% (fuel, electricity, personnel);

– achievement of wished environmental parameters of temperature and operating schedule desirable to consumers;

– high satisfaction for the beneficiary of the investment.

V. Conclusions

In the paper were presented results achieved by using a new concept of flow/return manifold necessary in designing and building hot water boiler rooms (max 115 °C) and for an effective distribution of heat carrier to users.

There were displayed the benefits obtained in comparison to the disadvantages of the traditional thermohydraulic schemes.

Although the new concept of manifold seems, at first glance, alike to the traditional metallic confections, it is different and gives the solution to a lot of negative issues that may arise in the implementation and operation of the boilers' room.

Studying different solutions, found by other authors such as Zortea Company (Germany), it has been concluded that they solve the same problems, but using other concepts and most of all with higher manufacturing costs for the metallic confections. In those solutions the metallic pieces can be executed only in the factory, with appropriate technology, so, by a limited number of executants.

Compared with other close concepts developed by other authors, especially Magra Company (Germany), the proposed solution, generates lower costs and can be applied into practice, for many executants (even if they do not have a complex workshop or factory at their disposal).

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