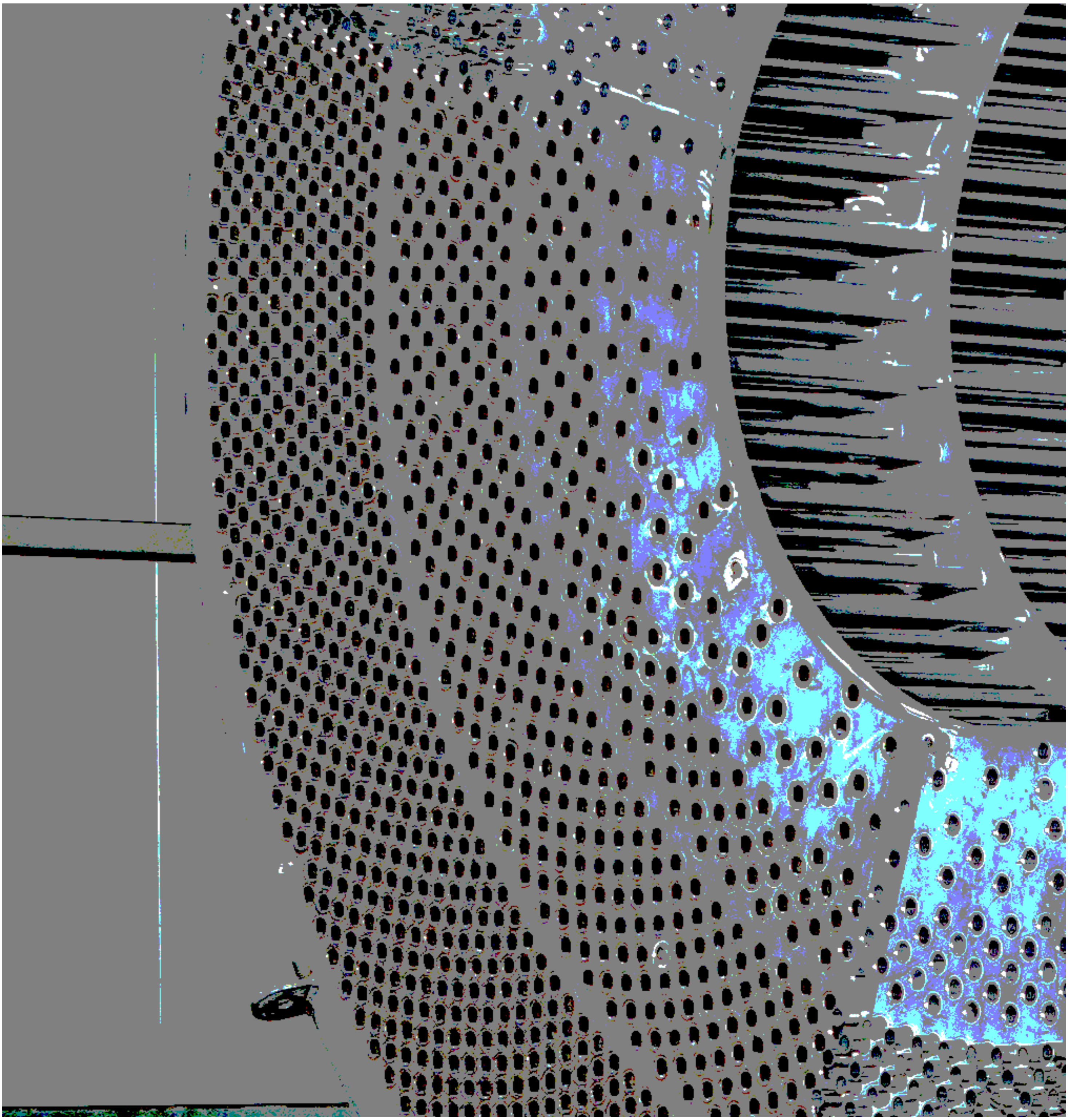


HUGO PETERSEN
Verfahrenstechnischer Anlagenbau

SULPHURIC ACID MANUFACTURE

Heat-Exchange Efficiency First – MBRF-Technology

www.hugo-petersen.de

The company

HUGO PETERSEN GmbH located in Wiesbaden, origins from the renowned engineering company Hugo Petersen, founded in 1906, in Berlin. HUGO PETERSEN is part of the Chemieanlagenbau Chemnitz (CAC) group and as such, can provide full support and security for the development and implementation of small to large scale installations.

Figure 1:
Hugo Petersen 1906

Initially, using the expertise gained in the classical production of sulphuric acid, from off-gases generated in the refining of metallurgical ores, the company HUGO PETERSEN specialized in the field of manufacture of sulphuric acid, hydrochloric acid and gas cleaning.

HUGO PETERSEN has more than 110 years of experience in the design and operation of sulphuric acid plants and their equipment. Today, HUGO PETERSEN offers a vast range of technology to this industry. The design, whilst incorporating HUGO PETERSEN's extensive experience, has been developed and optimised through a comprehensive research program, conducted using HUGO PETERSEN´S own pilot plant facilities. This, together with its 50 years know-how in the design and operation of gas cleaning equipment and plants processes, offers further advantages through the experience from both worlds.

The initial sulphuric acid tower technology invented by Mr. Hugo Petersen required since these days systems for irrigation of acids in the towers. Thus, from the very beginning the company was designing its own irrigation distributors.

About 50 well trained process technologists and engineers contribute their knowledge and expertise in the fields of mechanical and electronic engineering, as well as material science, to their design work.

Accurate Planning - the basis for our work

The scope of the tender, for a custom designed plant, is solely defined by the task, operating requirements and the requirements of our customer.

The thorough evaluation of the ecological and economic factors ensures the best plant specific solution. Proven technology, combined with HUGO PETERSEN´s site specific developments, leads to the construction of a plant suitable for the respective application.

HUGO PETERSEN has installed more than 400 turnkey plants and plant components for the manufacture of sulphuric acid, oleum and SO_2/SO_3.

Every plant is unique and all plant components have to be finely adjusted. Hence, it is of great advantage when a single company designs all components.

Efficiency in Heat-Exchange

The level of SO_2-emissions at sulphuric acid plants is directly linked to temperature management for the conversion of SO_2 to SO_3, which is handled by gas-gas heat exchangers. The number of Gas-Gas-Heat exchangers in the conversion sections forces plant designers to investigate in more compact and efficient equipment as these units are cost extensive. HUGO PETERSEN GmbH as an innovative company in this area developed the next generation of shell and tube heat exchangers, keeping in mind the environmental as well as economical aspects. The actual design of the radial flow heat-exchanger is its limited exchange surface to construction volume. The goal was to improve this ratio. This challenge has been successfully overcome in our new design the Multi-Bundle-Radial-Flow Heat-Exchanger (MBRFHEX), which is not only an optimum combination of the positive properties of the existing designs. In contrast to the current radial heat exchanger design with single tube bundle the new design consists of a multiple tube bundle which results into a compact design by optimized pressure drop. Out of this comparison the new design is far more promising than the existing ones. The first units demonstrate their excellence performance in several sulphuric acid plants. The new design assures that the gas distribution is nearly ideal and the effect of the MBRF-Concept supports the redistribution and homogenization of the temperature profile after each bundle. CFD-studies are demonstrating superior performance of the Design. Even this year the concept convinced clients in replacing their HEXs by the new MBRF-Technology.
The existing installations coped with extreme flexibility by and in some replaced up to three existing conventional Gas-/Gas-Heat-Exchangers. Like in a 1.500 t/d Mh pyrite/sulphur-burning plant. The unit have consider mixed operation of pyrite/sulphur in front of the intermediate absorption)

Temperature Management in Sulphuric Acid Plant

The operation of sulphuric acid plant means in first position managing the temperature at the contact reactor to get optimal conversion. If the temperature of gas inlet to a contact reactor is lower than ignition

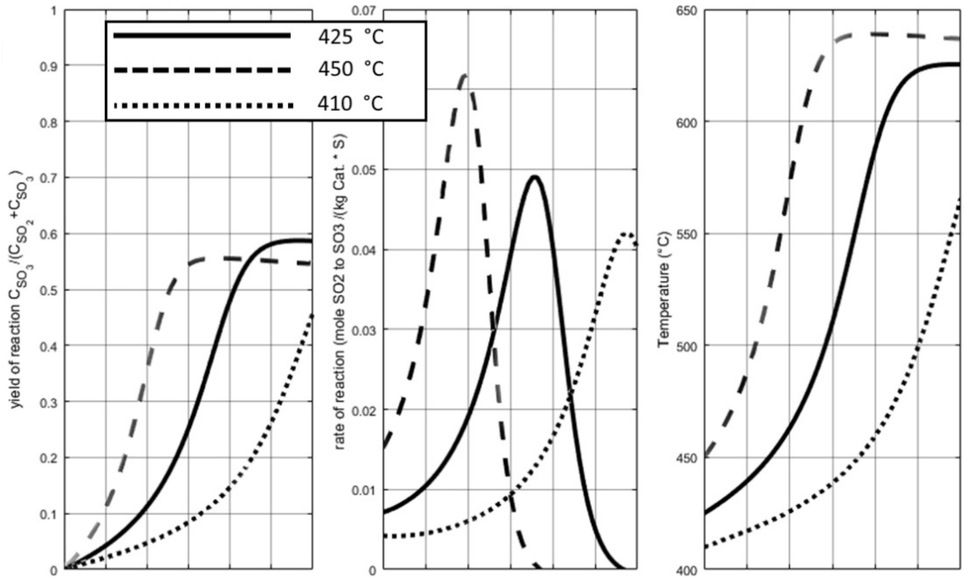


Fig. 1: Characteristics of the reaction in the reactor depending on gas inlet temperature vs. residence time of gas in reactor

temperature of the reaction SO_2 to SO_3 it will not ignite or will extinguish. Higher inlet temperature could lead to too high outlet temperature damaging the reactor. The gas / gas heat-exchanger have the task to keep the reaction at its optimal performance guaranteeing lowest SO_2-emission. In above figure 1 different inlet temperatures producing different yields in conversion.

Shell and Tube Heat Exchanger

Shell and tube heat exchangers are probably the most popular equipment for Gas-Gas heat transfer in sulphuric acid industry. The first generation of shell and tube heat exchanger was made by segmental baffles. Segmental baffle is a disc with a horizontal or vertical cut as shows in figure 2. The shell and tube heat exchanger is easy to manufacture by welding, which seals it for gas leakages and is safe for the operators. It also avoids mixing of cold and hot fluid. Shell and tube heat exchanger has a long life span with the possibility of corrosion protection.

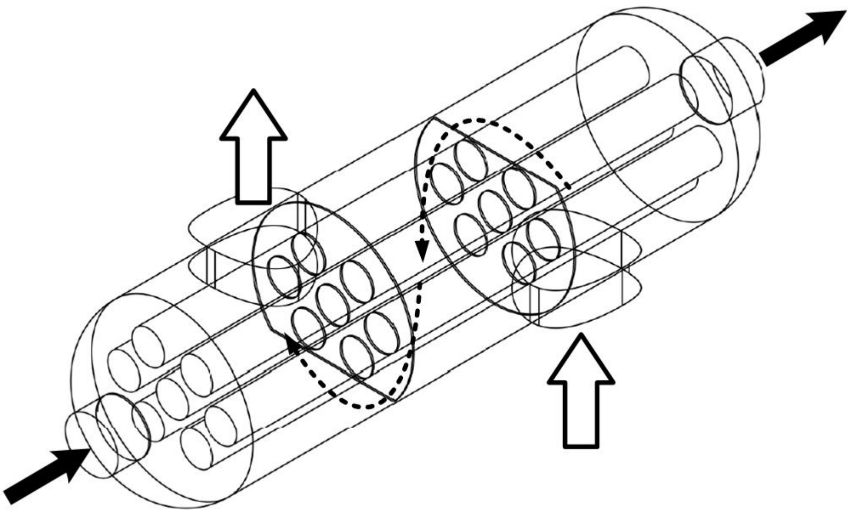


Fig. 2: **Shell and tube heat exchanger with segmental baffles**

The next innovation in shell and tube heat exchanger development was using disc and doughnut baffles instead of segmental baffles. In case of segmental baffles the flow patterns at the shell side are not uniform trough the length of the exchanger. Using disc and doughnut baffles averted this disadvantage. The second benefit of disc and doughnut baffles it prevents gas bypass between the outer tubes of the tube bundles and inside wall of shell (s. figure 3).

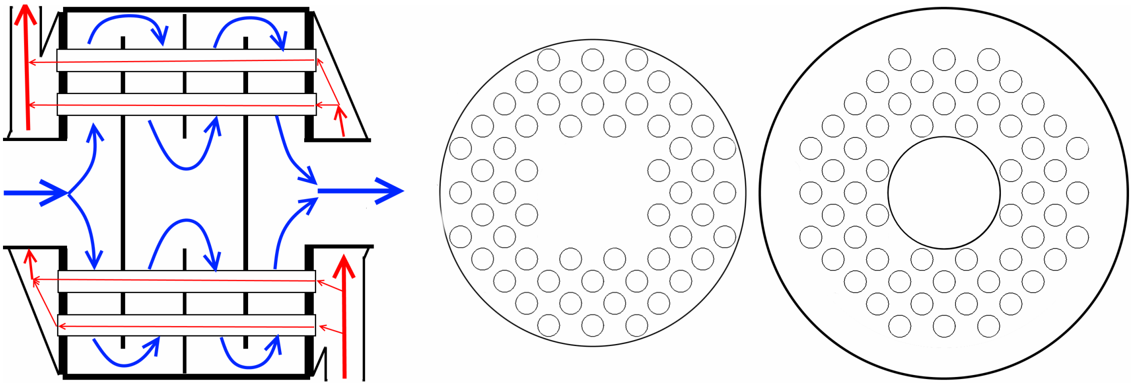


Fig. 3: **The operating principle of disk and doughnut heat exchanger**

The flow direction became radial but the tube arrangement was already staggered which caused inhomogeneous gas flow in tube bundles in radial direction as shows in figure 4.
Radial tube arrangement is the next step in development of exchanger which has homogeneous and uniform flow pattern all around the tube bundle (s. Figure 5).

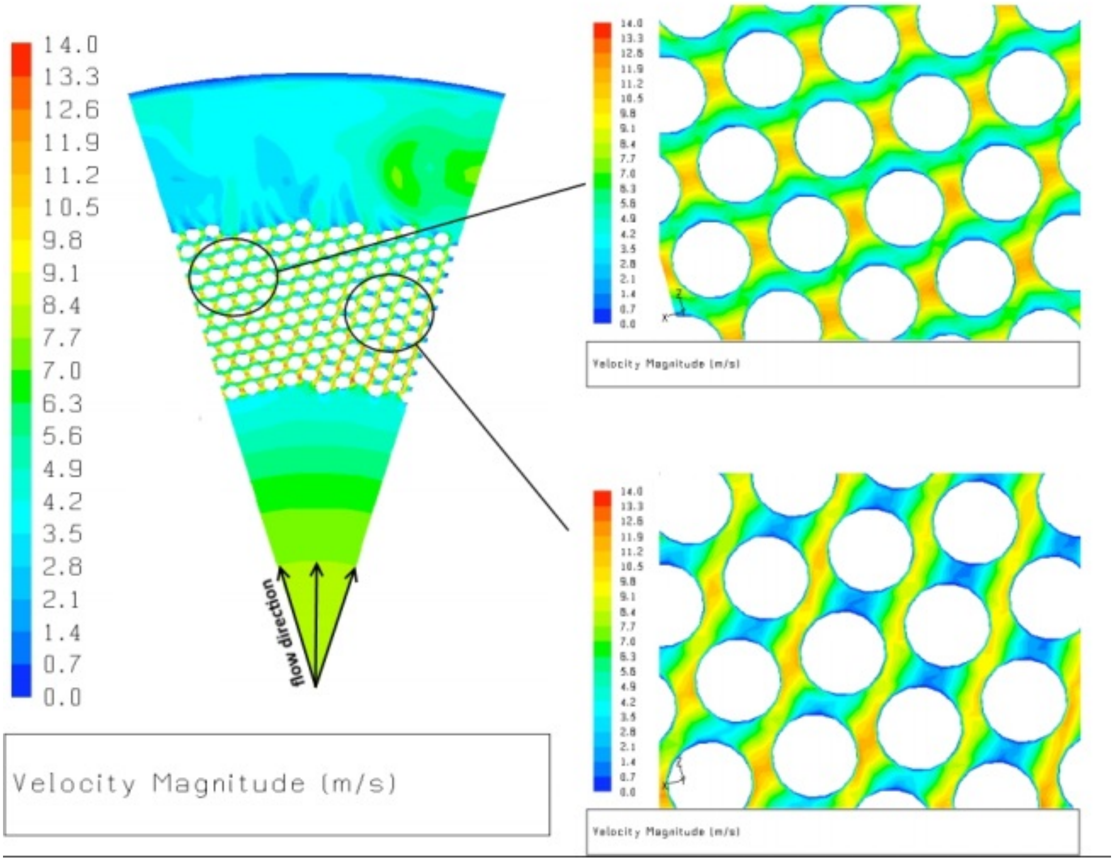


Fig. 4: radial flow through staggered tube arrangement

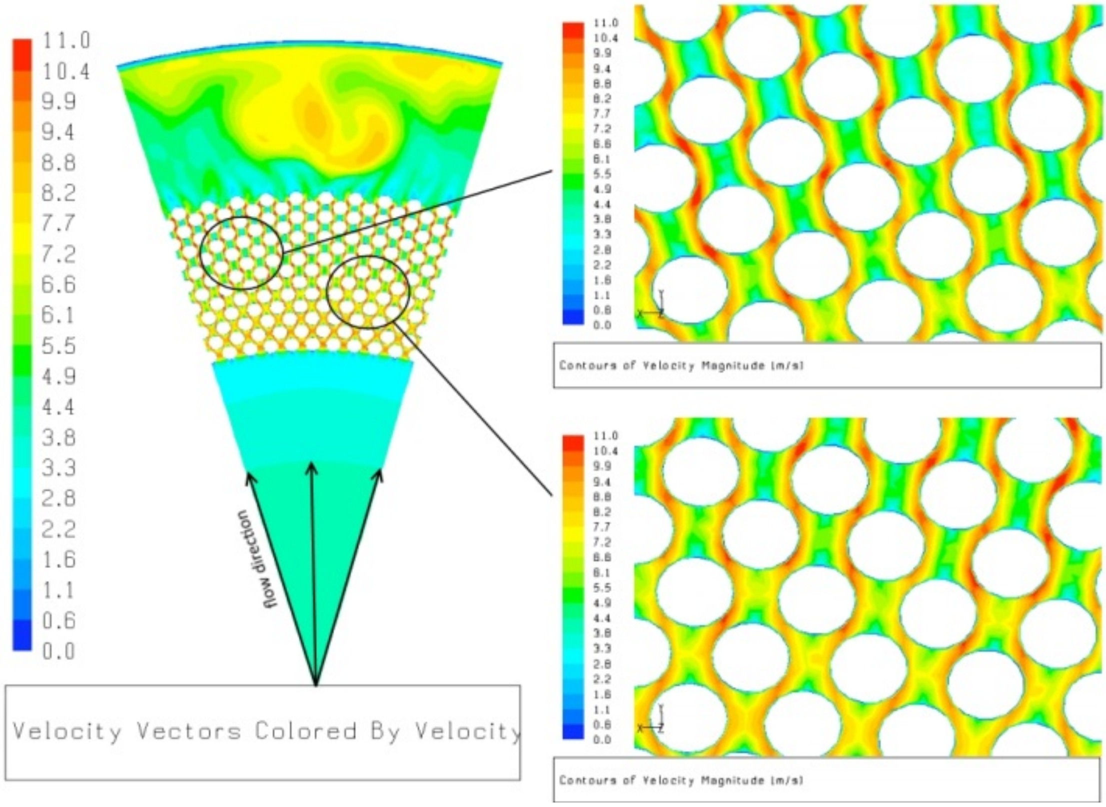


Fig. 5: **radial flow through radial tube arrangement**

Radial heat exchangers with radial tube arrangement have significantly lower pressure drop than staggered tube arrangement. Radial tube arrangement is totally rotational symmetric. Therefore a balance of mechanical as well as thermal stresses in circumferential direction is achieved.

However, radial tube arrangement with a constant pitch is limited in the number of tube rows in radial direction as illustrated in figure 6 left.

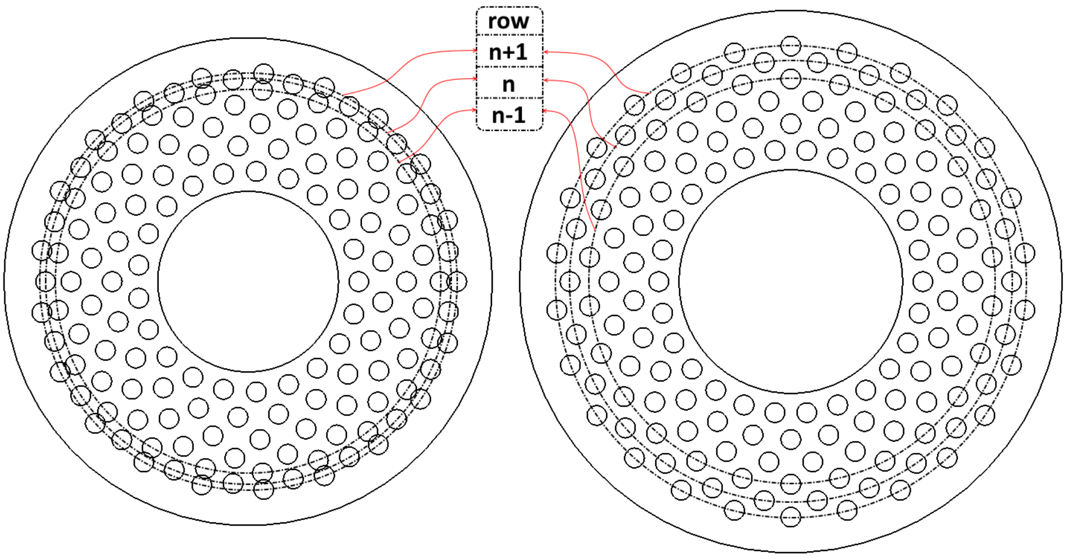


Fig. 6: **left: bottleneck in radial arrangement of tubes in a heat exchange right: greater internal duct diameter and therefore a greater exchanger overall diameter**

HUGO PETERSEN's innovative solution to overcome this problem is a radial heat exchanger with sequential arrangement of bundles as it illustrated in figure 6. Now the internal diameter of central duct of radial heat exchanger is the same as either inlet or outlet nozzle which is the minimum required diameter and not more. There is no limit for the number of tube rows and at the same time it is possible to choose a variable pitch (s. Figure 7).

In this design not only the pitch but also the number of tube bundles could be varied which allows allocation of unlimited number of tube rows in the heat exchanger.

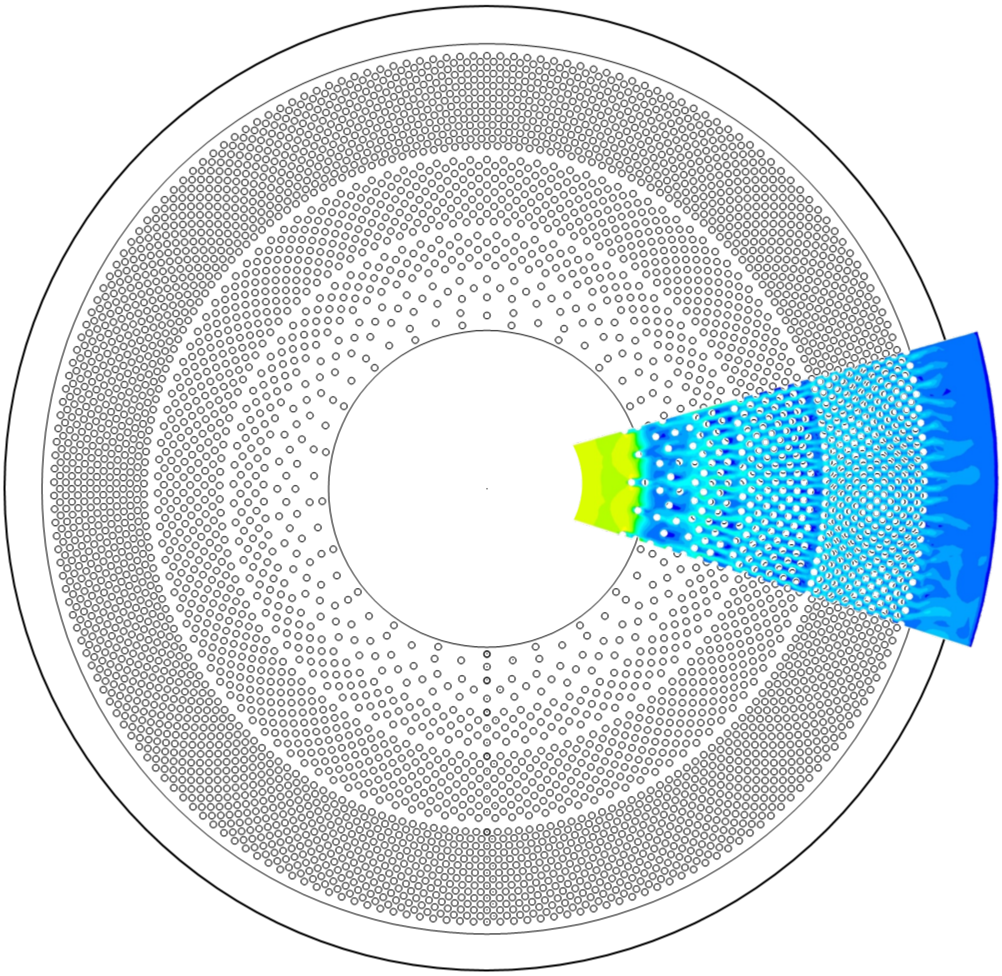


Fig. 7: HUGO PETSEREN new design of radial heat exchanger with sequential arrangement of tube bundles with radial tube arrangement and variable pitch

The new exchanger design has the benefits of classical radial exchanger like homogeneous and uniform flow pattern all around the tube bundles (s. figure 8). Additionally it has less pressure drop than the old design.

This creative innovation enables manufacturing of a more compact heat exchanger by a factor of at least 15% as illustrated in figure 9. It reduces the capital investment as well as variable investment due to lesser pressure drop and is more environments friendly.

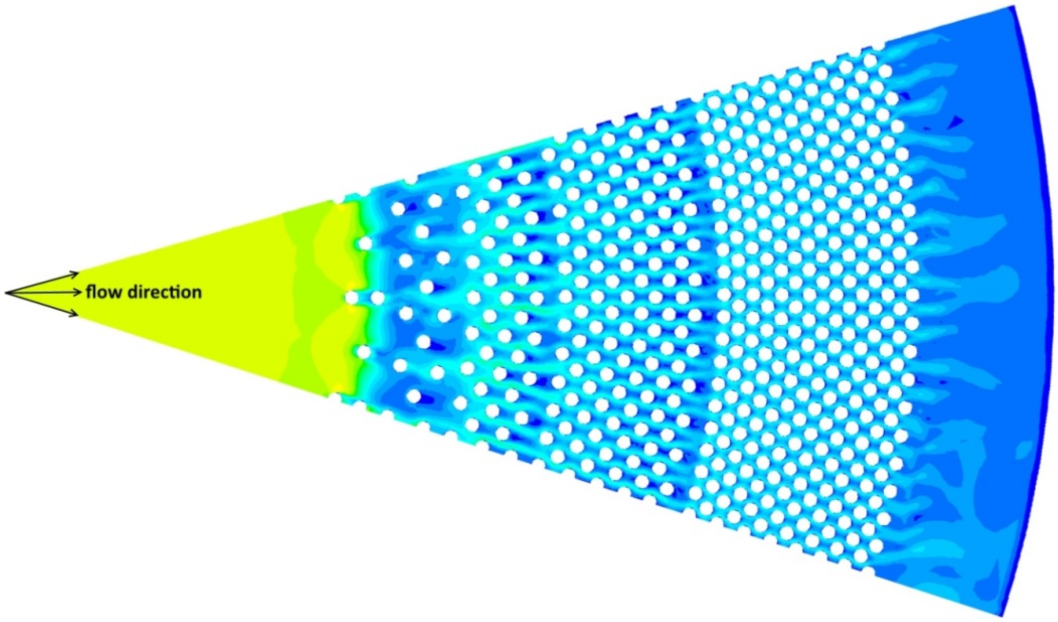
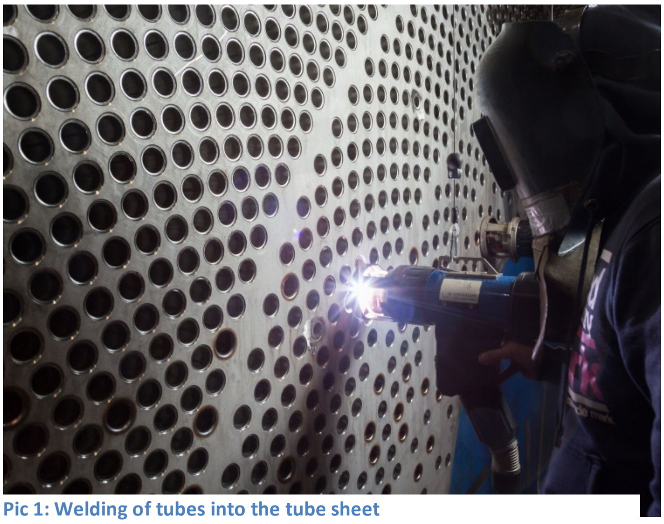


Fig. 8: uniform flow pattern along all tube bundles in radial as well as circular directions

We are firmly convinced, that radial multi bundle shell and tube heat exchanger should be a part of every new Sulphuric Acid Plant. For revamping of existing sulphuric acid plants it is a very economical way of prolonging the life time of the plants, especially if an increase in the plant capacity is required.



Pic 1: Welding of tubes into the tube sheet

The advantages of the exchanger are as follows:

- Feasibility of increasing the plant capacity
- no additional space required in case of increased plant capacity
- lower pressure drop
- higher specific heat exchange rate

The increased pressure drop by increasing plant capacity will be compensated by reduced pressure drop in the MBRF-heat exchangers. (patent pending)

Comparison Method

The decisive criteria for the choice of the heat exchanger designs are investment costs and variable costs.
The investment cost is proportional to the weight and dimensions of the heat exchanger. The costs of the heat exchangers with the same length and diameter are initially compared. Further the diameter of the heat exchanger is varied keeping the capacity constant. This comparison could be the basis of selection of the optimum heat exchanger which meets the process requirements with minimum investment costs.
The operating costs of the heat exchanger are proportional to the pressure drop.
Energy consumption of the main blower in a sulphuric acid plant would be higher with increase in the pressure losses caused by gas-gas heat exchangers. Thereby directly influencing the variable costs
The best choice must be compact, light in weight and minimizing the pressure losses.

Comparison

Bearing in mind the above mentioned criteria seven heat exchangers are worked out. The results are summarized in table 1.

The only heat exchanger with the same dimension (case A) as MBRF which could achieve the process requirement is the one with the segmental baffle. In the next step the exchanger diameters are increased (case B) until the minimal process required heat exchange is attained. In this case radial heat exchanger with radial tube arrangement as well as staggered tube arrangement could be used for the process as well.

MBRF is in comparison with the other kinds of heat exchangers

- as compact as segmental baffles heat exchanger but 30% lighter
- 8% more compact than radial heat exchanger with staggered tube arrangement and 27% lighter
- 13% more compact than radial flow exchangers with radial tube arrangement and 8% lighter

In all the cases the MBRF is compacter and lighter than other heat exchangers.

From the above comparison it is clear that the MBRF-heat exchanger is the best possible solution with the least investment costs.

Keeping in mind the environmental and economic aspects, HUGO PETRSEN’s engineers have successfully accomplished the best combination of compactness, weight and energy consumption with this new generation design of shell and tube heat exchanger.

	Specific heat exchange area (m² heat exchange area / m³ heat exchanger volume)	Pressure drop Shell-Side (mbar)	Heat exchange diameter (mm)	Weight (t)
Segmental baffle (A,B)*	29	72	5500	138
Radial (B) with staggered tube arrangement	41	180	6000	135
Radial (B)	30	41	6200	115
MBRF	34	30	5500	106
A) same Dimensions as MBRF B) same heat transfer capacities as MBRF *) calculating tool is HTRI Xchanger Suite® software HTRI is an acronym for Heat Transfer Research, Inc.				

Table 1: Selection matrix in accordance with the most important criteria of heat exchangers with different design for a heat transfer capacity of 10 MW

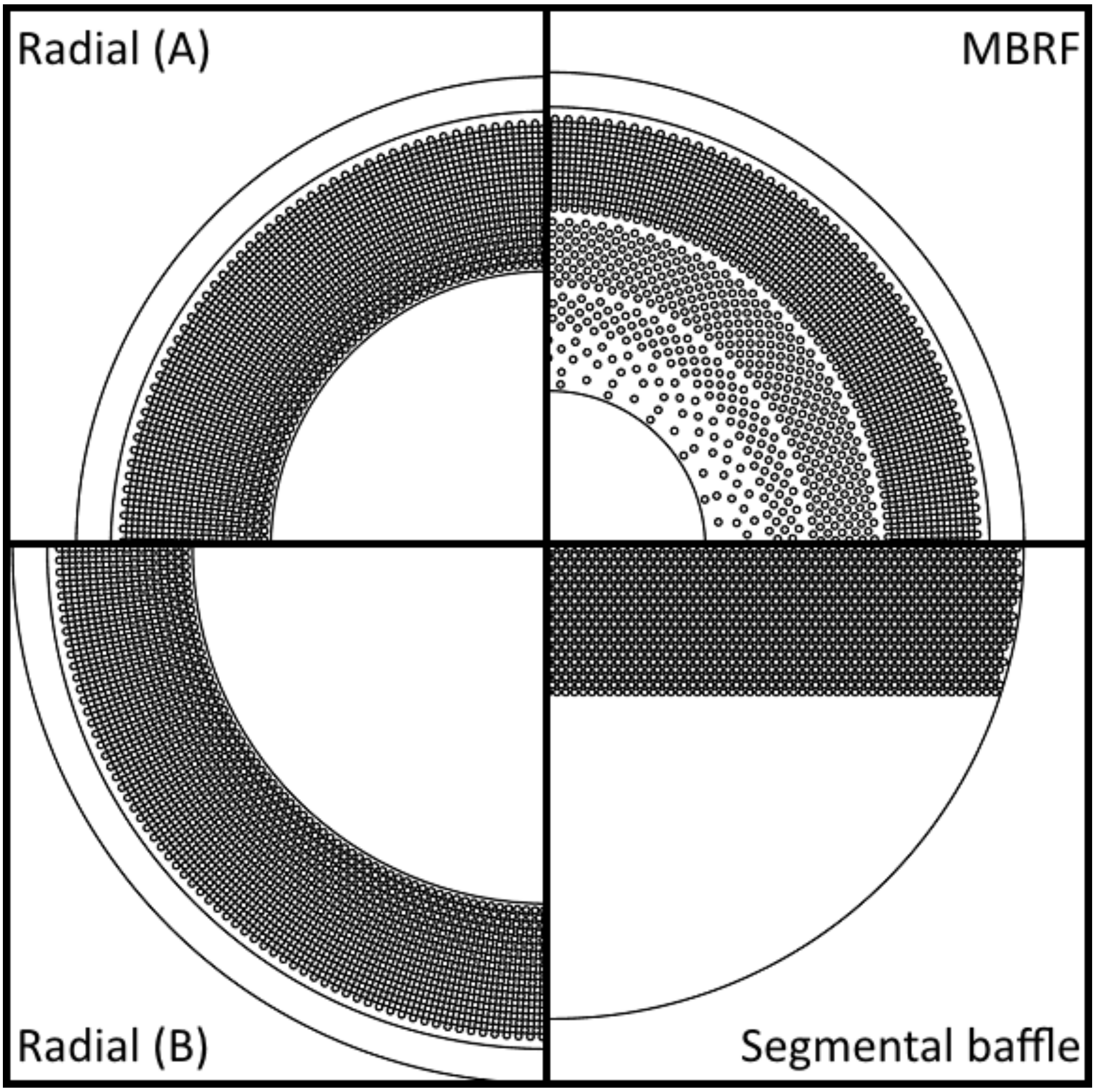


Fig. 9: **Comparison between Different Designs of Heat Exchanger**

References

Classical Shell&Tube Gas/Gas-Heat-Exchanger

Pic. 2: Conventional Shell & Tube-Gas/Gas-Heat-Exchanger in a Sulphur-Burning Plant of 550 t/d Mh

Classical Radial-Flow Gas/Gas-Heat-Exchanger

Pic. 3: Conventional Radial-Flow Gas/Gas-Heat-Exchanger in 1.800 t/d Mh Sulphur-Burning Plant

MBRF- Radial-Flow Gas/Gas-Heat-Exchanger

Pic. 4: MBRF- Gas/Gas-Heat-Exchanger in the workshop for a S-Burning Plant-Plant

Pic. 5: MBRF- Gas/Gas-Heat-Exchanger in a 1.500 t/d Mh Pyrrhotite-Roasting in combination of Sulphur-Burning

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