24 PROCESS HEAT SUPPLY REQUIREMENTS ON HTGRs

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Abstract

Since it has been claimed that the MHTGR is competitive with coal in producing electricity, the MHTGR must be competitive in producing process heat. There is a huge process heat market and there are quite a number of processes where the industrial MHTGR = HTRI could supply the necessary process heat and energy. However, to enhance its introduction on the market and to conquer a reasonable share of the market, the HTRI should fulfill the following major requirements: Unlimited constant and flexible heat supply, no secondary heat transport system at higher temperatures and low radioactive contamination level of the primary helium.

Unlimited constant and flexible heat supply could be achieved with smaller HTRIs having heat generation capacities below 100 MW-th. The process heat generated by smaller HTRIs need not be more expensive since the installed necessary heat supply redundancy is smaller and the excess power density lower.

The process heat at elevated temperatures generated by a HTRI with a secondary heat transfer system is much more expensive due to the additional investment and operating cost as well as the reduced helium temperature span available.

For some processes, the HTRI is not able to cover the total process heat requirement while other processes can consume only part of the heat offered. These limitations could be reduced by using higher core outlet and inlet temperatures or both.

Due to the considerably lower heat transfer rates and the resulting larger heat transfer areas in process plants, the diffusion of nuclear activity at elevated temperatures may increase so that a more efficient helium cleaning system may be required.

Introduction

Since it has been claimed that the MHTGR is competitive with coal in generating electricity, the HTGR must in general produce competitive process heat!

There is a huge market for process heat and in order to get a reasonable share of it, the HTGR's operating and design parameters have to be made more flexible for competiveness with the requirements of the broad potential customer spectrum in mind.

During a study, financed by the German Ministry of Research and Development (BMFT), Lurgi as a major process-oriented engineering company searched for and screened possibilities to provide the heat and energy needed for the operation of industrial plants with HTGRs having an energy supply capacity between 80 - 250 MW-th (= HTRI).

The processes considered potential candidates for coupling with a HTRI were selected on the basis of sufficient heat and energy demand in the operating temperature range of the HTRI (250° - 950°C) so that at least one HTRI was required.

The potential processes which could be supplied with energy and heat from a HTRI under these conditions are listed in table 1.

They are devided into three groups:

- In the upper group are the processes requiring virtually no further development work as production of process steam and district heating or only a relative small amount since their process temperatures are not higher than 500° - 600°C. This means the HTRI could from a technical point of view be coupled with them almost immediately. Practically all that is required is competitiveness and being accepted.

  The only exceptions are the aluminium oxyd production where heat has to be transfered to a powder like raw material at 900°C, which is conventionally common practice, and the refinery if hydrogen is required for upgrading heavier residues. The reformer for that purpose is developed.
- The second group has presently no market or requires substantial development work indicating that the prospects for coupling them with a HTRI are some what further in the future.

TABLE 1 POTENTIAL PROCESSES FOR HTRI HEAT SUPPLY

• Crude Oil Production
• Refinery
• Tarsand – Retorting
• Oilshale – Retorting
• Process Steam
• District Heating
• Seawater Desalination
• Aluminium Oxide Production
• Methanol
• Ammoniak
• Petrochemical Plants
• Cement
• Iron Ore Sintering
• Iron Ore Pelletizing
• Coal Gasification
• Burning of Clay

Methanol and ammonia plants are shut down due to over production and no change to the situation is at present in sight. Additionally they have to be coupled to the HTRI together with other plants, since they are able to consume the heat of the upper temperatur range from the HTRI only.

Petrochemical plants require a heat exchanger very sensitive to heat transfer rates around 900°C.

The lower group has both disadvantages. These processes require a large amount of development and do not have a market at the moment.

For some of them the HTRI is only able to supply their process heat demand partially since their maximum process temperature is above 950°C.

Lurgi has built, modernized and enlarged plants for almost all the processes shown in this table. Therefore, it has sufficient knowledge about the structural and operational requirements of such plants. Nevertheless additionally operators of such plants were contacted, especially some of the upper group, in order to discuss individually - after explaining to them the capabilities of the HTRI - Lurgi's interest in coopling the HTRI with their specific type of process plant. The most important points which resulted from this discussion are:

Requests on HTRI-Designers

First Request:

Reliable and Flexible Process Heat Supply

- such that the process plant operation is not influenced by a HTRI shut down due to required service or technical problems and
- the HTRI heat and energy generation is able to follow and can be adapted to the process plant demand efficiently.

The average European-size industrial complex requires process heat and energy in the range of 400 - 500 MW-th. It is shut down for general overhaul only once every four years.

Two HTRIs (200 - 250 MW-th) could satisfy its power and energy demand. However, if one of these two HTRs has to be switched off at least 50% of the process plant would drop out of production too. This is highly undesireable for the plant owners. They like to be protected against the financial loss.

In principle refineries, chemical and industrial plants do not usually contain only one major heat consuming reactor, but quite a number which are interconnected. Such plants are equipped with huge intermediate storage capacity, so that if one of these reactors has to be taken out of operation, the others can be supplied with process media and their production is not effected as the example of a refinery in fig. 1 shows. - The black circles represent tanks for intermediate storage. -

In fact, due to these measures one contacted refinery manager claimed proudly, our refinery has been in operation since 1956, despite the fact that we increased its production capacity and modernized it.

At the center of fig. 1 is shown the actual refinery. A nuclear energy supply is drawn to size into the refinery plant. It consists of 2 HTRIs which supply the refinery components with heat via a secondary heat transfer loop.

To satisfy such plant operator expectations the

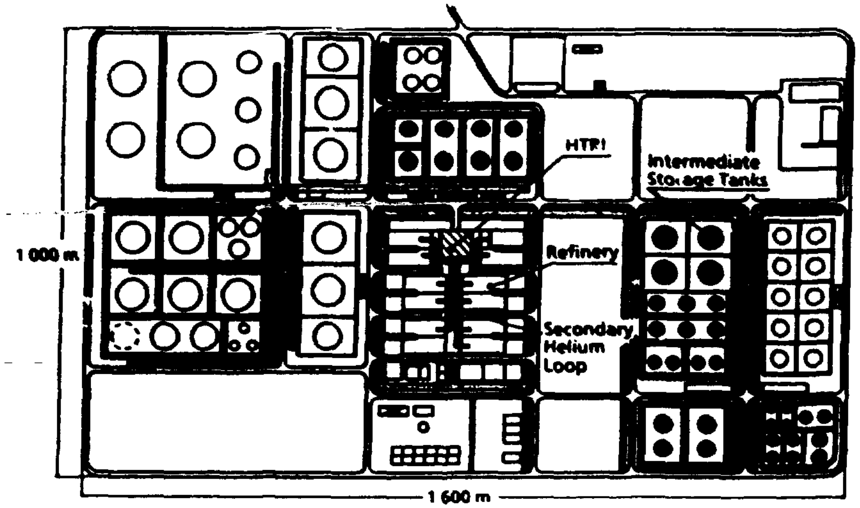

FIG.1. Layout of crude oil refinery with HTRI process heat supply.

Second Request

is therefore:

The HTRI Should be Offered Additionally with Lower Energy Output, Possibly Below 100 MW-th.

For the average european industrial complex this implies

- The plant would be equipped with 5 HTRIs plus one additional one or fossil fired helium heater as standby
- Each HTRI could then be serviced or repaired independently *without influencing the operation of the process plant.*

Figure 2 shows the helium heat supply requirements of the refinery shown in figure 1.

- The HTRIs could be selected such that they match the required energy demand over the process temperature profile more efficiently. This means, if there is f.i. only a small energy demand at the high temperature level, perhaps fewer HTRIs

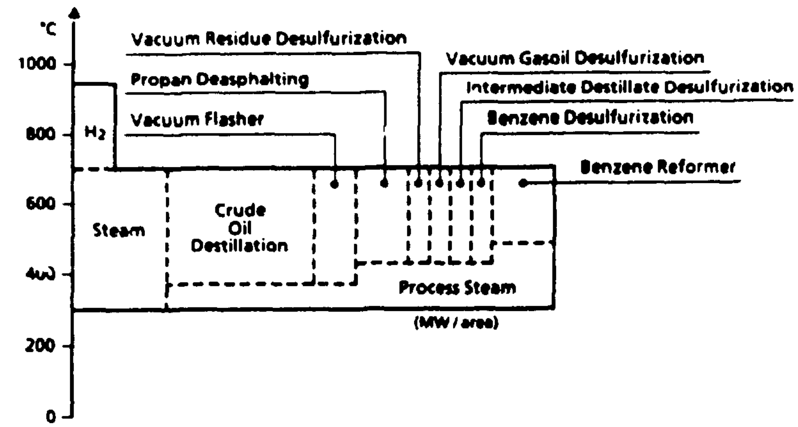

FIG.2. Process heat requirements of a refinery on HTRI (~400 MWth).

would be required with lower power density for the high temperature demand, allowing a higher average power density to be installed for the heat demand at the lower temperature level. *In other words getting the HTRI more competitive.*

- H_2-production between 700°C and 950°C
- Steam generation for electricity production between 300° - 700°C.
- Crude Oil distillation between 350° and 700°C etc.

To match such a power demand with the present HTRIs, two HTRIs are needed one with 170 MW for 950°C and one with 220 MW for 700°C. For a full redundant back-up power supply a reactor capable of delivering 170 MW at 950°C as well as 220 MW at 700°C or a fossil fired helium heater of equal capability is necessary. This would mean a 10% excess of expensive low power density installed for the reactors in operation and *a redunant power capacity of 44 % (fig. 3).*

This mismatch could be reduced with six HTRIs - one with 72 MW at 950°C and four with 80 MW for 700°C and one redundant one also capable supplying 72 MW or 80 MW - resulting in only 2% excess low power density and 20% redundant power capacity.

The reduction of both factors may make the version with the smaller HTRIs economically *more attractive besides its advantage of the higher* operational flexibility. The six smaler HTRIs could be almost 20% more expensive per installed MW as the three bigger HTRs and the complete

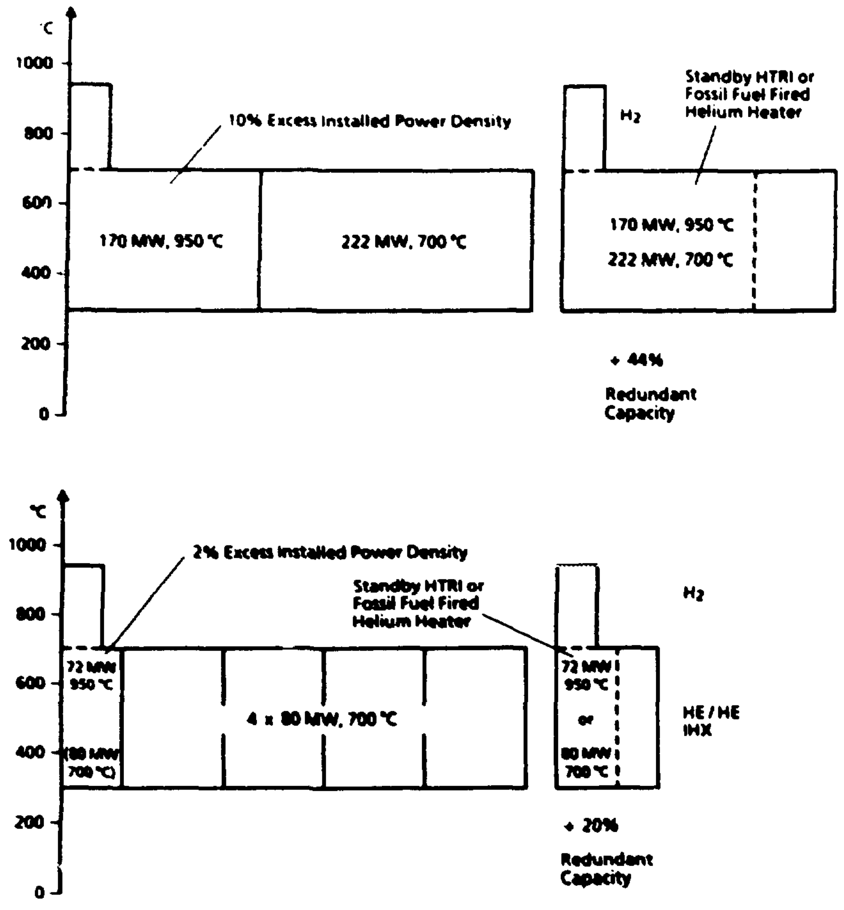

FIG.3. Possible HTRI size selections for refineries (process heat requirements: ~400 MWth).

power supply would cost the same. May be it is even sufficient to run the plant temporarely with 80% production eliminating the necessity for the redundant capacity.

The second example in figure 4 shows the possible HTRI-size selection for an aluminum oxide plant where heat has to coupled in from 770°C - 950°C for the calcination of aiumininum oxide, from 760°C - 770°C for

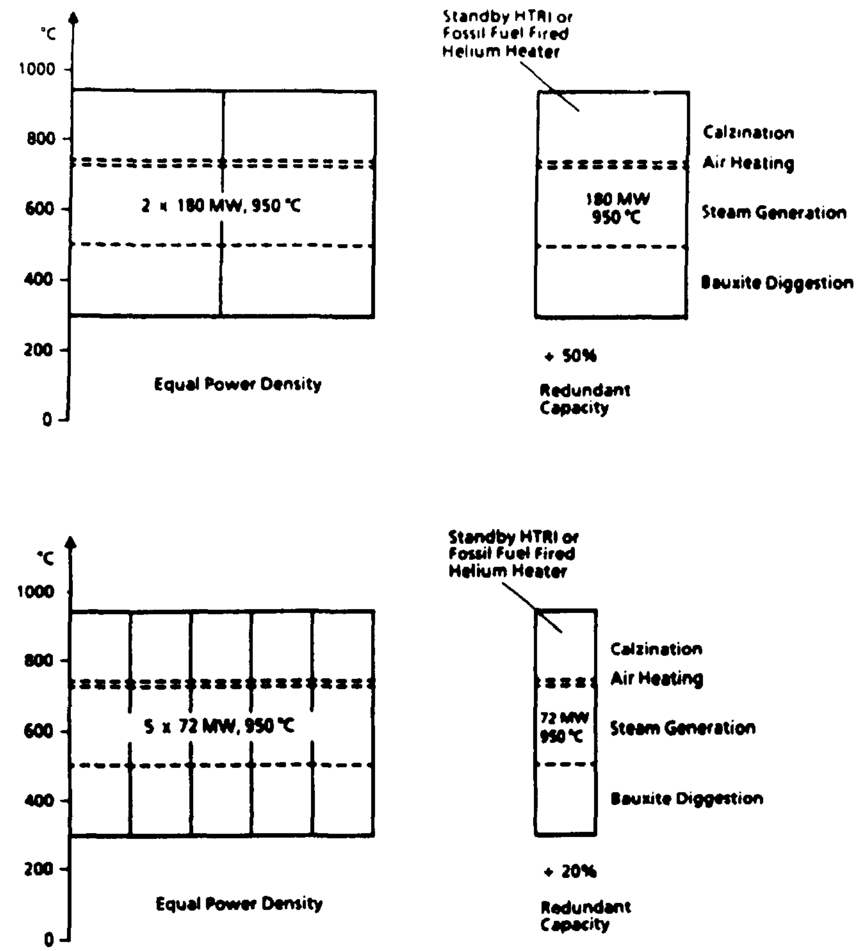

FIG.4. Possible HTRI size selections for an aluminum oxide plant (process heat requirements: ~360 MWth).

heating air, from 485°C - 760°C for generating steam and from 300°C - 485°C for bauxite digestion. Where low core power density can be used only due to the bigger demand at higher temperatures.

Again two conventional size HTRIs could be employed to capacity.

However small size HTRIs would still also have the advantage of less redundant power capacity required, 20% against 50%, if necessary, in addition to their heigher operational flexibility.

A request from the process plant builder, as well as in the interest of the reactor builder is:

Third Request

A Secondary Heat Transfer Loop at Plants with Higher Process Temperatures Has to be Avoided.

Figure 5 shows the result of an iron-ore-sintering plant investigated in this respect. A HTRI process heat supply without a secondary heat transfer system could be competitive with coke breeze, heating gas and electricity as the usual energy sources at a sintering plant requiring two to three with 170 - 200 MW-th each. With a secondary heat transfer system, due to the additional equipment needed and operating costs, the HTRI process heat is too expensive.

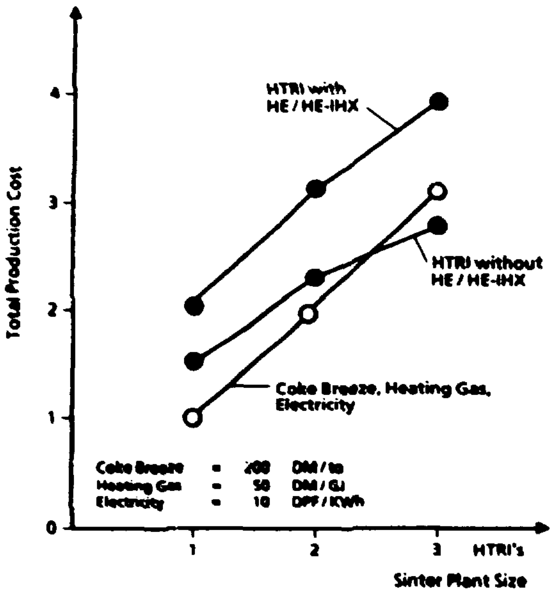

FIG.5. Iron ore sintering cost comparison.

To avoid a secondary loop possible radioactive contamination of the primary helium should not exceed a certain level. This means, if a leak developes between the primary helium and the process medium, the contamination of the process medium has to be negligible in comparison with its natural radioactivity.

For maintaining the radioactivity release at any situation below the allowable level the

Fourth Request

is:

The Primary Helium Cleaning System's as Well as the Primary Loop's Retaining Capabilities of Nuclear Activity has to be Sufficient at any Situation and Time.

Due to the lower heat transfer rates and the resulting larger heat transfer areas in process plants, the diffusion of nuclear activity at elevated temperatures will increase so that a more efficient helium cleaning system may be required . - With helium heat transfer rates in the range of 450 Watt/m² °C are possible. By transfering heat to solids in the form of powder, 250 watts/m²°C is approximately the maximum.

Table 2 shows once more the processes where the HTRI could supply the heat and energy. Additionally it shows the very theoretic HTRI potential for the three groups.

TABLE 2. ESTIMATED HTRI (200 MWth) POTENTIAL

• Crude Oil Production • Refinery • Tarsand – Retorting • Oilshale – • Process Steam • District Heating • Seawater Desalination • Aluminium Oxide Production	> 2000
• Methanol • Ammoniak • Petrochemical Plants	> 500
• Cement • Iron Ore Sintering • Iron Ore Pelletizing • Coal Gasification • Burning of Clay	> 500

In table 2 from the aluminum oxide production downwards the introduction of the HTRI could be enhanced by raising the HTRI core outlet and inlet temperatures. The potential of these processes comprises quite a portion of the total HTRI-potential.

In the case of some the top process temperature can be provided by conventional means only. This means burning gas or oil. Others require heat at the high temperature of the HTRI supply only, so that most of the heat generated has to be converted to electricity or another purpose be found as mentioned before. This may result in ineffective HTRI employment.

As table 3 shows, raising the HTRI helium inlet temperature by 100°C, which should be technically possible, and raising the HTRI helium outlet temperature by 50° - 100°C would increase the HTRI use.

TABLE 3. GAIN OF HTRI USE BY RAISING HELIUM INLET AND OUTLET TEMPERATURES (°C)

	Inlet	Outlet	% - Change
Aluminium Oxide		950 -> 1000	95 -> 100
Ethylen		950 -> 1000	More Eff. HX
Methanol	300 -> 400	950 -> 1000	46 -> 58
Ammonia	300 -> 400	950 -> 1000	15 -> 25
Iron Ore Sintering		950 -> 1050	90 -> 100
Iron Ore Pelletizing		950 -> 1050	60 -> 75
Coal Gasification		950 -> 1050	All Types of Coals

Naturally, process changes have to be investigated too in order to make the power supply matching easier. For instance reducing the maximum process temperature at the aluminum oxide production. This is a question of what aluminum oxide quality the electro-furnace, producing the final product aluminum, can operate satisfactorely with.

The

Fifth Request

is therefore:

HTRI Design Allowing More Flexible Inlet and Outlet Temperatures Towards High Temperatures

Summary

There is a huge potential market for the HTRI as process heat supplier. For receiving an appreciable share of it , the HTRI should be offered

- In a smaller unit additionally besides the sizes 170 - 250 MT-th

  for more

  - efficient power requirement-matching,
  - operational flexibility,

  and

  - operational reliability

- With high reliable operation time

- Without the necessity of a secundary heat transfer loop at higher process temperatures

  for

  - competitiveness through a very effective helium cleaning system and activity retaining capabilities

  as well as

- With more flexible inlet and outlet temperatures

  for

  - covering more efficient a wider range of applications

  and naturally

- at a lower price.