THE FLUCTUATING STEAM REQUIREMENTS AND FEASIBLE APPLICATION OF GAS TURBINES WITH A WASTE HEAT BOILER

A. PENNINGER, B. CZINKÓCZKY and Á. KÓBOR

Department of Heat Engines
Technical University, H-1521, Budapest

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Abstract

We introduce a Hungarian petroleum refinery with an industrial heat requirement fluctuating between 460 MW and 150 MW and evaluate the feasibility of a 300 t/h steam producing gas turbine with heat utilizing boilers while guaranteeing the provision of necessary operational safety reserves. The most suitable solution is accomplished with a continuous loading operation of the gas turbine block, due to the small requirement of steam there is an occurrence of periodic excess, which is utilized in the 215 MW steam turbine to acquire an operational safety reserve. During the period of maximum steam requirement, an inadequate steam quantity is acquired from these steam turbines, this can be secured by extraction before reheating. From the result of this analysis, it is not practicable to fulfil the fluctuating steam requirement of the gas turbine under partial loading.

Keywords: gas turbines, heat boilers.

The Százhalombatta thermal power plant, on the Danube, continuously supplies the nearby petroleum refinery with 17 bar pressure industrial steam between a maximum of 46 MW and a minimum of 150 MW heat output without any failure. Presently this task is accomplished in 230,000 hours functioning time with an old power plant and 90,000 hours with a condensing steam turbine equipped with extraction before reheating. This is shown in *Fig. 2*.

The age of the power-plant makes its reconstruction to be compulsory, presently a new G1 block is being built with a 143 MW output Siemens/KWU gas turbine and a 255 MW heat output Borsig-made heat utilizing steam boiler.

This is just the first part of the installation program, a similar G2 block is also planned, due to the fact that the heat output of one plant cannot meet the whole industrial steam requirement. However, apart from the peak heat-requiring period, the two gas-turbine blocks in operation can supply enough steam for most of the year. But for utilization a 62 MW output condensing steam turbine is necessary, due to this, the G2 block will

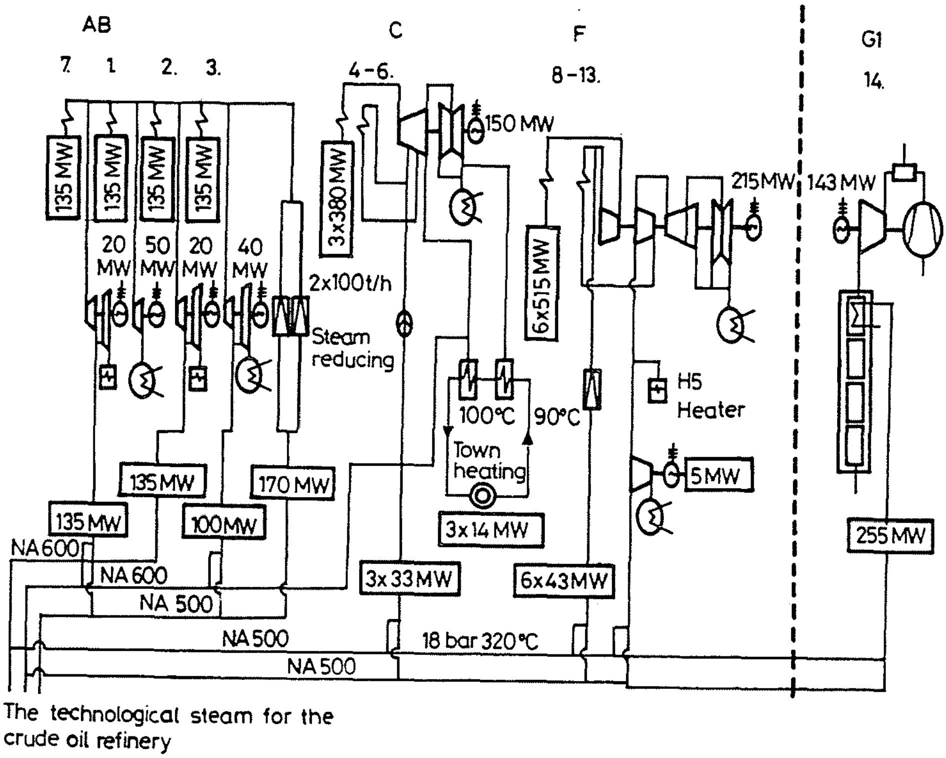

Fig. 1. The technological steam for the crude oil refinery

not only be a temporary block but also a combined cycle power-plant block. In the case of power failure the G1 and G2 gas-turbine power-plant blocks have the ability of providing reserves (during low steam requirement).

If any form of power failure should arise during the installation of G1 block, the present power-plant blocks could immediately provide usable reserve steam supply. The 215 MW blocks, with the kind of heat connections shown in *Fig. 1*, proved to be suitable for the serve of the excesses. The 17 bar pressure industrial steam collector tracks the condensing steam turbines before reheating; steam can be produced from unregulated pressure extraction. If the extracted pressure is above 100 MW, the output will exceed the required 17 bar pressure level, in the case of lower output the steam supply will only be enough for reheating and offsetting the turbine regulator valves. Presently each of the 215 MW steam turbines is sufficient for the production of 43 MW of heat output, though there is a plan for increasing the steam production up to 150 t/h with the regulation of

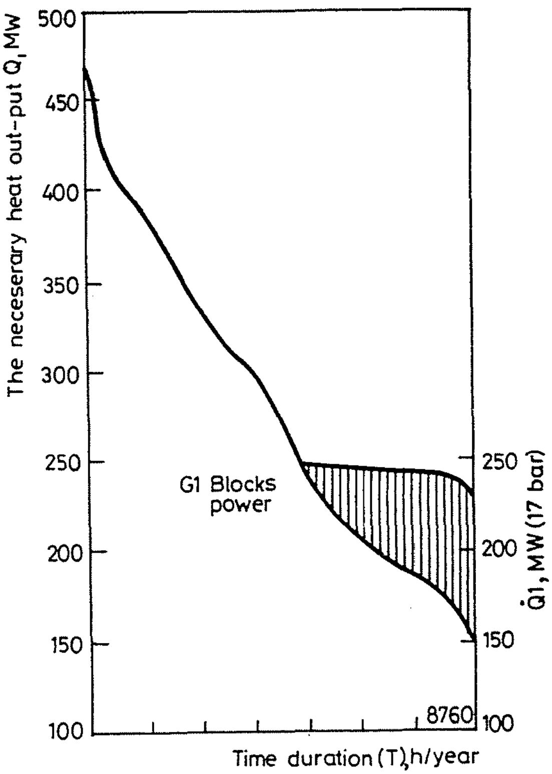

Fig. 2. The necessary heat output

the industrial valves upsetting process. This drastic steam supply increase became necessary because of certain periods, like electrical loading-valley periods, when out of the six blocks only one or two operate and only on minimum loading. This results in a very expensive use of hydrocarbon (oil-gas) in the thermal power plant, causing the plant to operate as a peak power plant.

In the interest of continuous production, the petroleum refinery requires two operating 215 MW power-plant blocks permanently. Due to this, the steam requirement is 150 t/h from each block, so as to keep the 300 t/h steam output of the heat utilizing boiler in continuous operation without breakdown.

In the case of industrial breakdown the old power-plant block cannot be taken into consideration as a reserve, because of its very long starting time; it is therefore not reliable when immediate replacement is required.

Under the local industrial conditions, diagram number two shows that by following the yearly steam requirement duration-diagram, the following alternatives arise:

1. The G1 and G2 power-plant blocks are operated in accordance with the original steam requirement plan, and the excess steam quantity is being processed in the new condensing steam-turbine.
2. During the omit of the G2 power-plant block, the G1 power-plant capacity would not be to accommodate with the high increase in the steam requirement not even under maximum loading, the alteration takes place from the breakdown reserve, provided by the permanently operating two 215 MW power-plant blocks (the two 215 MW power plants provide minimum steam requirement of 50 t/h only for emergency reserve purposes).
3. During the omit of the G2 power-plant block, for the production of the high steam requirement, the G1 power-plant operates in accordance with the above point number 2 in supplying a low steam requirement, the G1 power-plant block is put onto maximum loading and the excess steam quantity is processed in the reserve containing 215 MW steam turbines.

The first solution is unsuitable, due to the maximum installation cost and the implementation of expensive imported equipment when the nation is trying to decrease the use of high power consuming equipment and products for more economical ones. On this basis, this version is not realistic. Especially when we take into consideration the expected fall in steam requirement in comparison to the calculation of the year 1987 and the expected increase of the crude oil world-market price. This will also result in a decrease in the utilization of the petroleum refinery.

Further we examined only the second and third possibilities and found that the third solution is more advantageous than the second, so it is the most practicable version.

The advantage of this version over the second version is based on the fact that the continuously rotating axle of the gas-turbine's shaft speed efficiency decreases more than that of the 215 MW steam-turbine's with an output compensation for excess outflow.

The second and third version can be implemented, considering the fact that the six 215 MW blocks have the necessary steam pipelines for reheating before extraction and for supplying the 215 MW steam-turbines and unit-turbines from the 17 bar industrial steam system. The same applies to supplying the H5 preheater from the fifth extraction process. Theoretically, there is a possibility of recirculating the heat utilizing boiler's excess steam before reheating, through the seventh extraction process. This is only possible in the turbine with a minimum loading of 100 MW, due to this the excess heat output acquired in the reheating process becomes lower compared to the recirculation accomplished through the fifth extraction (this is shown in *Tables 1* and *2*).

Table 1

Calculation for the yearly heat saving of the gas-turbine block under permanent complete loading, (the two reserve steam-turbine blocks under optimum loading)

Excess steam quantity from G1	t/h	25	50	75
Heat utilising boiler's steam flow	t/h	275	250	225
Heat utilising boiler's loading	%	91.6	83.3	75.0
Gas turbine's loading	%	85.5	72.0	62.5
Gas turbine's relative fuel consumption	—	0.89	0.79	0.705
Gas turbine's absolute fuel consumption	kg/s	7.97	7.09	6.32
Excess fuel consumption	kg/s	0.985	1.881	2.643
Gas turbine's excess heat consumption	MW	48.45	92.52	130.0
Gas turbine's excess output	MW	21.07	40.69	54.50
F block(s) unit turbine's foreign steam	t/h	25.0	45.2	45.2
E5 foreign heating steam quantity	t/h	0	4.8	29.8
Total excess output	MW	26.73	51.76	70.48
The 215 MW block's heat consumption output decrease due to compensation	MW	80	154	199
Total excess heat consumption decrease	MWA	48.45	92.52	130
Occurring heat consumption decrease	MW	31.51	61.48	69
Utilisation hours from the duration diagram	h/year	1850	2110	—
Yearly heat saving	MWh/year	58367	129723	—

The pressure from the fifth extraction remains under 17 bar in all possible loadings, this is why we directed the excess steam inlet in accordance with the first diagram.

The advantage of this solution is the high heat saving, the applicability not depending on the loading rate and the usability of the present pipelines and connections. Due to all these advantages, extra installation cost is not required by this solution. The pressure that arises from the G1 block's excess steam could be used to warm up the H6 preheater, this results in a very great heat saving. Unfortunately, the present pipeline connection is unsuitable for this, so new pipelines have to be installed for the six 215 MW blocks.

On the basis of steam requirement in the year 1987, the G1 block heat utilizing boiler's steam output was 3960 hours more than normal requirement and with 92.5 t/h maximum excess steam supply. The two operating

Table 2

Calculation of the yearly heat saving of the G1 block under permanent complete loading, (the reserve F block is under minimum loading)

Excess steam quantity from G1	t/h	25	50	75
Heat utilising boiler's steam flow	t/h	275	250	225
Heat utilising boiler's loading	%	91.6	83.3	75.0
Gas turbine's loading	%	85.5	72.0	62.5
Gas turbine's relative fuel consumption	—	0.89	0.79	0.705
Gas turbine's absolute fuel consumption	kg/s	7.97	7.08	6.32
Excess fuel consumption	kg/s	0.985	1.881	2.643
Gas turbine's excess heat consumption	MW	48.45	92.52	130.0
Gas turbine's excess output	MW	21.07	40.69	54.50
Foreign steam quantity before reheating	t/h	25	50	75
Reheatable excess heat consumption	MW	2.49	4.98	7.47
F block's main turbine excess output	MW	6.09	12.19	18.29
Total excess output	MW	27.16	52.88	72.79
The 215 MW block's heat consumption output decrease due to compensation	MW	84	156	207
Total excess heat consumption decrease	MW	50.94	97.50	137.47
Occurring heat consumption decrease	MW	33.06	58.50	69.53
Utilisation hours from the duration diagram	h/year	1850	2110	—
Yearly heat saving	MWh/year	61161	123435	—

215 MW steam turbines that produce steam supply reserves are capable of processing the maximum excess steam for the propulsion of the unit turbines and warming of the H5 preheater. During the operation of the G1 block under complete loading and with the above excess steam processing, more electrical output tends to be generated than the present requirement.

Heat saving arises if the above excess electrical output is being processed within the power-plant (that is, some other operating output reducing F blocks), or, if this kind of plant is not available, then the compensation can be in a similar output reducing 215 MW blocks. The heat consumption significantly reduces in the compensating blocks, whereas there is an increased output in the G1 block due to the maintenance of complete output.

In summer, excess steam is created in the G1 block, due to this, we calculated +15°C environmental temperature to be the optimum value for the gas-turbine's complete loading, normally proper complete loading indicates 145 MW electrical output and 442 MW heat consumption. During our calculation, we assumed that the G1 block's excess steam processing and the excess electrical output compensating blocks are being operated by the burning of natural gas, so during comparison we can only use the heat consumption.

This comparison is shown in *Tables 1* and *2*, by making use of 25 t/h, 50 t/h and 75 t/h excess steam as the adapted parameters. The heat saving was calculated in accordance with diagram number two, on the basis of 1987's heat requirement duration-diagram and utilization time data.

The excess output compensating block's heat consumption decrease was decided from *Fig. 3*.

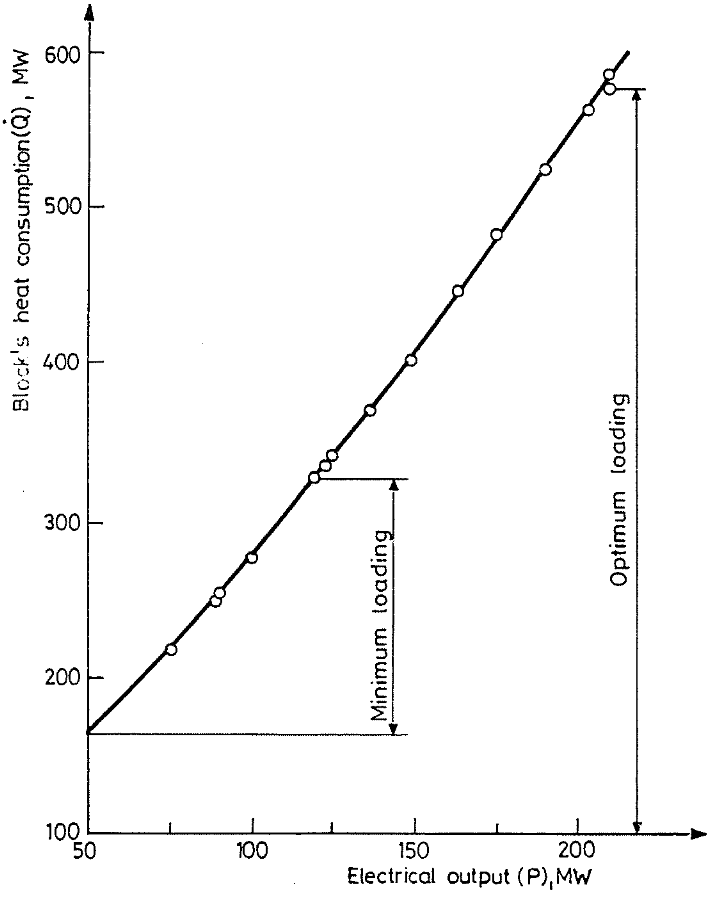

Fig. 3. Block's heat consumption

Within the range of the examined partial loading, in comparison to the complete loading of 300 t/h value, the steam output of the heat utilizing boiler decreased by 75% and the gas turbine's electrical output by 62.5%.

If in-return of decrease steam requirements, we operate the gas turbine with complete loading till the end, in order to save heat, practically this does not have an effect on the life-span. According to the KWU industrial diagram, the existing smoke-gas temperature had no effect on the life-span, because when the output was above 65% the value was continuous till the end.

Table 1 shows that the yearly heat saving calculation in the reserve F blocks was optimum when the loading was 190 MW. In this situation refeeding before reheating was not possible and the fifth extraction with refeeding brought a 52.247 GJ/year heat saving in the third version, compared to the second version.

The table shows that during the calculation of the annual heat saving and under minimum loading of the reserve F blocks, refeeding before reheating was possible. In this situation, the saving was 51.277 GJ/year in the third version compared to the second. With complete loading the G1 block's yearly heat saving amounts about 5% of yearly heat consumption, this value is quite significant. Considering these results, we therefore suggest the application of the third version.

Address:

Dr. PENNINGER Antal
Dr. CZINKÓCZKY Botond
Dr. KÓBOR Ágota
Department of Heat Engines
Technical University
H-1521, Budapest, Hungary