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ANALYSIS OF THERMAL CENTRE FAILURING

Thermal centre failuring is the cause of high costs for the companies administering the centres, its consequences influence heat recipients. Since failuring occurs mostly during the periods of the greatest demand for heat (autumn-winter-spring), and the fact that thermal centres are exploited throughout the whole year, there is a necessity to monitor their technical condition. That is why introducing failure analysis is crucial to identify the effects causing malfunctioning of individual elements of a given thermal centre.

***Keywords**: thermal centre, failuring, analysis.*

1. Introduction

A thermal centre is a complex technical system, which is to convey heat of precisely defined parameters and amount from the heat distribution network to recipients. Thermal centres are a part of heat distribution systems (a subsystem) and at the same time they constitute an administrative border between the heat distribution network user (a heat producer), and the inner system user inside a heated building (a heat recipient). Figure 1 presents a block diagram of a heat distribution system.

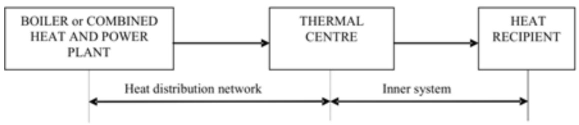

Fig. 1. Block diagram of a heat distribution system

Considering the importance of thermal centres, it is crucial for them to be highly reliable since the costs of heat supply intervals are incurred by both the thermal centres users as well as the recipients.

The only way to increase the reliability of thermal centres is to analyse the causes of their failuring, which will make it possible to identify and eliminate the factors causing failures in the future.

Thermal centres are classified according to various criteria, which very often, thanks to their complexity, do not render their individual features. Figures 2 and 3 present demonstration diagrams of a thermal centre.

1.1. Thermal centre components

- pipelines:
- automatic regulation sets comprising of :
  - regulators:
    - with a discontinuous output signal (double, triple, and impulse),
    - with a continuous output signal (pneumatic, hydraulic and electric);
- measuring systems:
  Physical quantities, whose measures are taken are as follows: temperature, pressure (differential pressure) and the flux or the heating factor volume;
- actuator:
  - regulation valves,
  - servo-motors valves;
- protective elements (safety valves);
- elements replenishing water depletion within an installation;

Replenishing water depletion within an installation powered by a thermal centre takes place from the heat distribution network (from the primary pipe). Crucial elements of each replenishing system are cut-off valves and a water-meter for measuring water to be replenished;

- stabilising elements:
  - diaphragmatic expansion tank for boiler,
  - pressure stabilisers.

Stabilisers constitute of : a pump, a tank and automatic pressure regulators, which include a pressure sensor, a regulator and an electro-magnetic valve.

- heat exchangers;
- pumps.

2. Analysis of thermal centre failuring

Decomposing a thermal centre makes it possible to analyse its structure. Figure 4 shows a sub-division of a given thermal centre to be analysed as well as its basic components.

Red-marked elements are the ones which were notified broken in the data base. Thermal centre decomposition was conducted up to level 2 which indicates that the composition of individual elements was of minor importance, and consequently the causes of failuring were not estimated every time it was malfunctioning

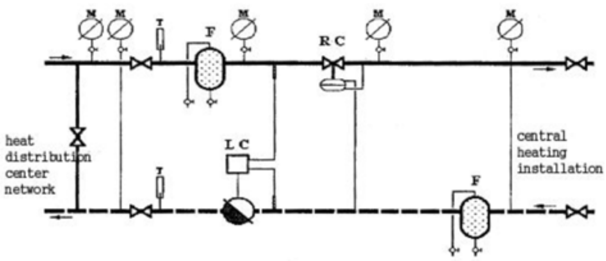

Fig. 2. Thermal centre diagram of direct connection without parameter transformation [2]: RC – differential pressure regulator, LC – heat meter, F – sludger filter

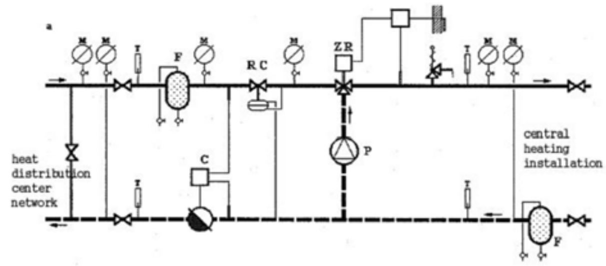

Fig. 3. Pump mixing node diagram with a pump in the mixing circuit [2]: RC – differential pressure regulator, P – mixing pump, C – heat meter, F – sludger filter, ZR – control valve

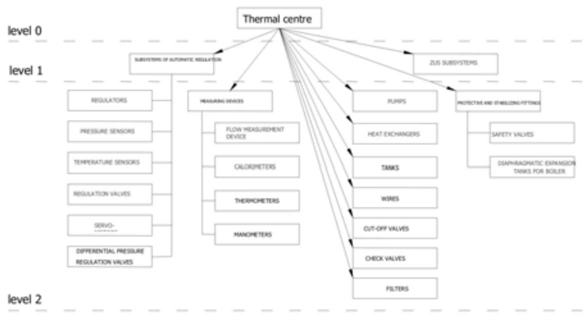

Fig. 4. Thermal centre decomposition

(in the data base provided by Toruńska Energetyka Cergia SA only few devices were provided with the exact cause of their failure).

Failure of a given device leads to entire thermal centre breakdown (even though in some cases the centre could still complete some of its functions) and consequently it is vital to take actions in order to make it fully efficient. There are 2 kinds of actions: repairing or replacing a broken device with a new one of the same or better parameters. When it comes to pressure stabilisers only repairing is possible since this system is viewed to be complete and connected (there haven't been a single case of simultaneous replacement of all the elements at once).

For the purpose of this analysis failuring rates have been enumerated - w_u. This rate stands for the quotient of the number of failures of a given device throughout the whole year and the general number of failures noted during the year.

Table 1 presents the number of thermal centres maintained by the Toruńska Energetyka Cergia SA at the time of research.

2.1. Failures of pressure stabilisers (ZUS)

There were 343 failures during the time of research. The greatest number of them occurred in 2004, namely 67 failures (19%), the smallest – 8 failures (2%) – in 1997. As presented in Table 6 up till 1999 the number of failures was minute, approximately 12 occurrences a year, whereas between 2000-2005 the average number of failures rose up to 47. The year 2000 constitutes a distinct boundary separating those two periods, this is when the number of failures rose noticeably (from 13 in 1999 up to 64 in the year 2000).

In the case of pressure stabilisers actions to be taken to make them efficient and operational comprise only of repairs which also included replacing some parts with brand new ones, such as a pump or a regulator. Not a single case of replacing the entire pressure stabiliser with a new one was identified. The failuring rate w_u is presented in Tab. 2.

2.2. Calorimeter failures

Within the research period there were 2366 calorimeter failures. Most of them were noted in the year 2002 – 908 (38%), the smallest number in 1995 – 41 (1,7%). Throughout the whole research period the number of failures in the following years increases or decreases against previous years, however no noticeable deviations could be observed (the greatest variation is to be depicted between 1996 and 1997, when the number of failures increases by 125, which accounts for 5,2% of the general number of events). The year 2002 is exceptional, as the number of failures increases dramatically (in comparison to 2001 the number of failures rises by 744 which accounts for 31,45% of all events of that kind during the researched period). It is closely connected with the fact that in the year 2002 there was a change in the Law on Measures thus some calorimeters installed between 1994-99 could no longer be viewed reliable and lost their measuring properties (the law defined the correct properties of a calorimeter, whereas in Poland before that time there were various solutions applicable connected with storing data, display format, etc.). Some calorimeters needed to be legalised. Having operated for 5 years calorimeters with a blade circulation transducer have to be taken for a major overhaul, whose costs come to 80% of the price of a new one – therefore, in the result of a tender, the calorimeters which did not meet the criteria of the new law were replaced.

Actions to be taken in order to bring the devices back to their original shape were: replacements with new ones 43% (1028 cases) and repairs 57% (1338 cases).

Calorimeter failuring rate w_u is presented in Table 3.

2.3. Pump failures

Between 1995-2005 there were 146 pump failures, with the greatest number – 48 (33%) in the year 2005, and the smallest – 2 (1,36%) – noted in 1996, 2002 and 2003.

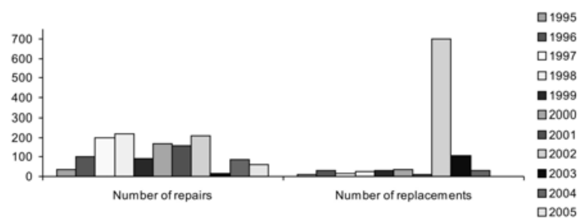

Fig. 5. Calorimeter failures

Tab.1. The number of thermal centres.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Number of centres	1209	1225	1229	1249	1269	1294	1333	1349	1340	1358	1385

Tab. 2. Failuring rate for pressure stabilisers

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
w_u	0,0500	0,0349	0,0112	0,0218	0,0269	0,0856	0,0602	0,0249	0,0927	0,1115	0,0657

Tab. 3. Calorimeter failuring rate:

	1995r	1996r	1997r	1998r	1999r	2000r	2001r	2002r	2003r	2004r	2005r
w_u	0,1708	0,3267	0,3570	0,3769	0,2479	0,2375	0,3527	0,5795	0,2520	0,1947	0,1073

In the years 2004 and 2005 there was a dramatic increase in the number of replacements in accordance with the company's invest plans. UPE pumps were purchased and fitted to suit central heating purposes and UPS pumps for hot useful water. Pumps used before that time had gland sealing between the engine and the pump connected with the atmosphere. 80% repairs of the above mentioned pumps dealt with replacing that sealing and the bearings, which were flooded resulting from the sealing damage. UPE pumps are constructed in such a way that the connection of the engine and the pump is inside it and it is flooded with water all the time.

Actions taken to bring pumps back to their original shape were 58% repairs (85 cases) and 42% replacing with new ones (61 cases).

Pump failuring rate w_u is presented in Table 4.

2.4. Pressure transducers failures

Within the research time pressure transducers were out of order 31 times. Most failures – 12 (39%) were noted in 2005, whereas in 1995-1997, 1999, 2001-2003 no damages were reported.

Actions taken in order to bring pressure transducers back to their original shape were 71% (22 cases) repairs and 29% (9 cases) replacing with new ones.

Failuring rate w_u for pressure transducers is presented in Table 5.

3. Analysis of thermal centre failuring

Within the research period there were 6933 thermal centre failures. The greatest number of them - 1567 (22%) occurred in 2002, whereas the smallest in 1995 – 240 (4%). During that time there were 4740 repairs and 2193 replacements with new ones which respectively stands for 68% and 32% of all the actions taken in order to restore the thermal centres' usability. The greatest number of repairs and replacements with new ones was noted in 2002 - 566 and 1001 respectively. Table 6 presents the quantification of thermal centre failures.

According to the data presented in Table 6, apart from the year 2002, the number of all failures per one centre was smaller than 1. The year 2002 is exceptional since in that time a great number of calorimeters and devices measuring the flow had to be replaced. The year 1995 is the most efficient since the rate is 0,20.

In 2002, 65% of centres failed, whereas in 1995, only 170 centres failed which constitutes 14% of all the centres.

4. Analysis according to maximal and minimal criteria of w_u rate

Table 7 presents the figures of failuring rate of all the elements analysed during the researched period. Table 8 presents the greatest failuring rates throughout the years. According to Table 7 between 1995-2005 calorimeters and servo-motors were most prone to failure. During six (1996, 1997, 1998, 2000, 2001, 2002) out of 11 years of the researched period it is calorimeters that have the greatest failuring rate. In 2002 it is extremely high - 0,5795 and its rate is the greatest from amongst all the maximum failuring rates noted at the time of the research. During the remaining 5 years (1995, 1999, 2003, 2004, 2005) is it servo-meters that have the highest failuring rate.

5. Summary

According to the results of the research the greatest part in the failuring structure during the researched period belongs to failures of calorimeters and servo-motors. Their failures constitute respectively for 34,13% and 20,64% of all the causes of thermal centre failuring. The smallest part belongs to failures of exchangers and safety valves - respectively 0,10% and 0,12% of all the failures. For calorimeters and servo-motors, whose failures constitute for over 50% of all the thermal centre failures

Tab. 4. Pump failuring rate

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
w_u	0,0167	0,0050	0,0139	0,0140	0,0310	0,0238	0,0151	0,0013	0,0040	0,0449	0,0830

Tab. 5. Failuring rate w_u for pressure transducers

	1995r	1996r	1997r	1998r	1999r	2000r	2001r	2002r	2003r	2004r	2005r
w_u	0,0000	0,0000	0,0000	0,0031	0,0000	0,0107	0,0000	0,0000	0,0000	0,0133	0,0208

Tab. 6. Quantification of thermal centres' failures

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Number of failures	240	401	717	642	484	748	465	1567	496	595	578
Number of failed centres	170	251	389	395	321	451	294	882	345	358	324
Complete number of all the centres	1209	1225	1229	1249	1269	1294	1333	1349	1340	1358	1385
Number of failures per one centre	0,20	0,33	0,58	0,51	0,38	0,58	0,35	1,16	0,37	0,44	0,42
% of failed centres	14,06	20,49	31,65	31,63	25,30	34,85	22,06	65,38	25,75	26,36	23,39

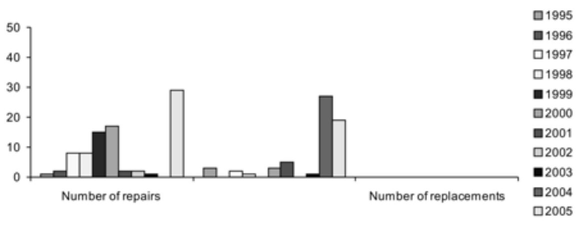

Fig. 6. Pump damages

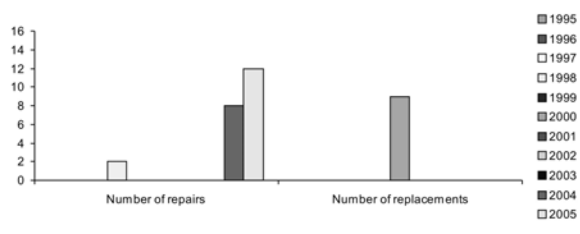

Fig 7. Pressure transducers failures

Tab. 7. Figures of failuring rate w_u noted during the researched period

		w_u										
Lp.	Device	1995r	1996r	1997r	1998r	1999r	2000r	2001r	2002r	2003r	2004r	2005r
1	ZUS	0,0500	0,0349	0,0112	0,0218	0,0269	0,0856	0,0602	0,0249	0,0927	0,1115	0,0657
2	Servo-motor	0,3083	0,2095	0,1478	0,1978	0,2541	0,1698	0,1914	0,1078	0,3327	0,2962	0,3270
3	Calorimeters	0,1708	0,3267	0,3570	0,3769	0,2479	0,2674	0,3527	0,5795	0,2520	0,1947	0,1073
4	Flow measuring devices	0,1708	0,1446	0,1353	0,1044	0,1653	0,1524	0,1355	0,2017	0,0786	0,0682	0,0640
5	Pumps	0,0167	0,0050	0,0139	0,0140	0,0310	0,0267	0,0151	0,0013	0,0040	0,0449	0,0830
6	Regulators	0,1292	0,1072	0,2120	0,1651	0,1901	0,2019	0,1570	0,0562	0,1512	0,1664	0,2163
7	Regulation valves	0,0375	0,0499	0,0265	0,0421	0,0269	0,0160	0,0151	0,0038	0,0282	0,0266	0,0277
8	Pressure sensors	0,0125	0,0050	0,0070	0,0093	0,0227	0,0040	0,0129	0,0006	0,0000	0,0000	0,0000
9	Temperature sensors	0,1042	0,1172	0,0893	0,0654	0,0351	0,0642	0,0602	0,0243	0,0605	0,0549	0,0761
10	Pressure transducers	0,0000	0,0000	0,0000	0,0031	0,0000	0,0120	0,0000	0,0000	0,0000	0,0133	0,0208
11	Safety valves	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0067	0,0069
12	Exchangers	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0067	0,0052

Tab. 8. Maximal w_u rates noted during the researched period.

	1995r	1996r	1997r	1998r	1999r	2000r	2001r	2002r	2003r	2004r	2005r
name	Servo-motors	Calorimeters	Calorimeters	Calorimeters	Servo-motors	Calorimeters	Calorimeters	Calorimeters	Servo-meters	Servo-meters	Servo-meters
w_u	0,3083	0,3267	0,3570	0,3769	0,2541	0,2674	0,3527	0,5795	0,3327	0,2962	0,3270

an exception to the rule was made at the stage of formulating preliminary assumptions for the analysis. Therefore, decomposition of the thermal centre was expanded up to the level 3. It is crucial, however, to remember that the causes of calorimeters and servo-motors failuring were defined on the basis of partial data analysis – the one providing precise and unequivocal descriptions of failuring of the above mentioned devices.

Failures connected with batteries going dead were filed only if the battery went dead before its nominal time (provided by the producer).

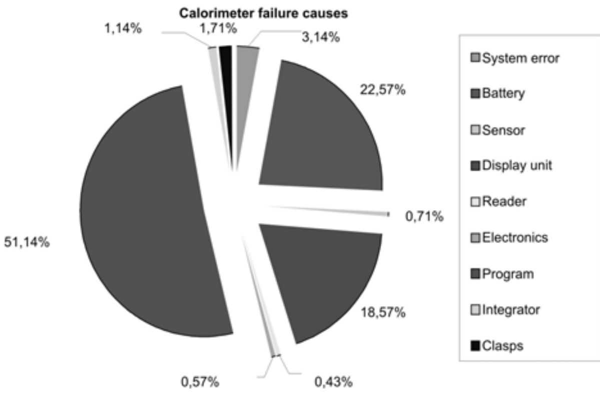

Fig. 8. Causes of calorimeter failures

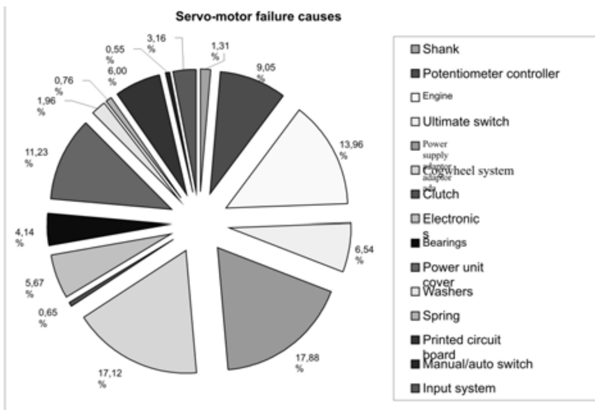

Fig. 9. Causes of servo-motor failures

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