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ENERGY SYSTEMS IN INDUSTRY: INDUSTRIAL BUILDINGS AND STEAM - TRAP TYPES

Abstract: Some research results obtained by investigation of industrial energy systems are given here.
Energy and energy cost flows evaluated in industrial building show that there are cases where the use of degraded energy for heating purposes does not lead to energy and cost savings. This energy in cooling period induces electrical energy unnecessary spending. The investment fan diagrams proved to be very useful in return time energy conservation investment research.
Joint steam-trap rating table and misapplication one are presented. Multiple upstream and downstream misapplication influences on the other steam-traps in steam and condensate system is revealed. The water hammer effect leads to additional operational cost losses and bach stream effect to investment losses.

1. INTRODUCTION

Energy conservation research is very significant because of its effects on energy resources conservation. Also with energy savings goes smaller thermal load and pollution of environment. Economic effects can be noticeable.

Very often there is such a research on residential buildings but there is not a lot of research done on industrial buildings. Here energy and energy cost flows through industrial buildings were investigated. Steam technology energy system is one that in these buildings takes blame for its low efficiency functioning so this time steam-traps as parts of this system were taken in our focus. Some main results obtained are presented here.

2. INDUSTRIAL BUILDINGS

2.1. Sankey diagram [1]

Fig. 1. shows Sankey diagram for garment industry building as result of bottom-up analysis of this industrial building. Dashed lines denote this industrial building energy system. There are four energy carriers entering

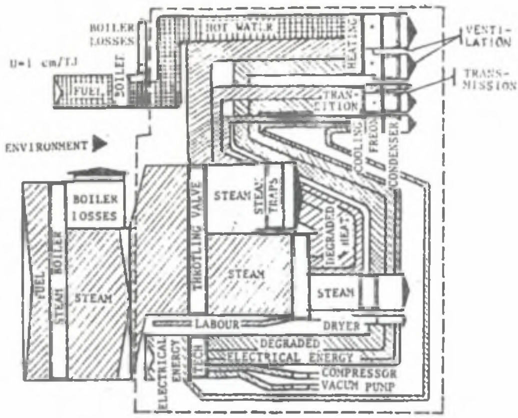

Fig. 1. Energy flow inside the industrial building
Rys. 1. Przepływ energii wewnątrz budynku przemysłowego

this energy system: steam energy, electrical energy for technology, electrical energy for cooling and hot water energy for space heating. Quantities of hot water and electrical energy agree well with results of top to bottom analyses of this energy system but steam does not. This difference is attributed to steam-trap loss in this system. In this diagram one can differentiate technology electrical energy usage by vacuum pump, compressed air generation and these energies are afterwards dissipated into environment. But other degraded electrical energy dissipated into the space of building is previously used for motor running, lighting and technological heating. Different ways of steam usage can be also seen (drying, presses, irons and other technological processes). After these usages degraded heat is also dissipated into environment or in the building space. Additionally different energy loads in the building space used in different temporal periods: heating, transition and cooling are shown. Degraded technology electrical and steam energies used in the heating period lessen the need for hot water energy for space heating by in the cooling period of time these energies induce the use of electrical energy needed for cooling devices running. In the transition period there are no any such effects.

2.2. Cost flow diagram [2]

In Fig. 2 the cost flow paths are given. Their widths correspond to actual cost values. Electrical energy is very expensive on the market so the ratio of unit price of particular energy to unit price of oil used for steam and hot water boiler C = 3.08. Steam production is also expensive

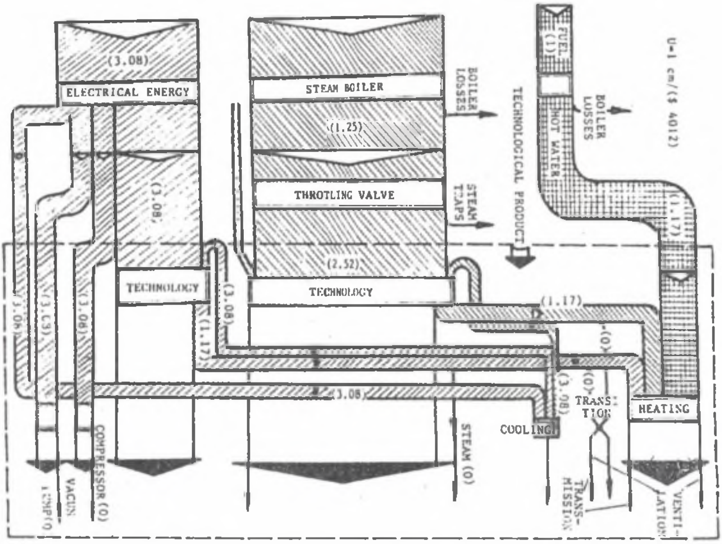

Fig. 2. Energy cost flow inside the industrial building. Ratios of unit price of particular energy to unit price of fuel are given inside parentheses as (C)

Rys. 2. Rozpływ kosztów energetycznych wewnątrz budynku przemysłowego. Stosunki jednostkowych kosztów poszczególnych rodzajów energii do jednostkowego kosztu paliwa podano w nawiasach jako (C)

but the reason is the loss of the energy when steam is produced in boiler and dramatic energy loss when this steam is distributed (steam-traps) C = 2.52, which is high comparing to C = 1.17 of hot water for space heating. This is why degraded steam energy of intentionally non-insulated surfaces of steam devices and steam pipes can not save energy costs in the winter so this should be avoided where it is possible. There is even greater penalty imposed on energy system in summer because of non-insulated steam pipes and devices. Electrical energy will be spent for space cooling. In socalled transition period of year degraded technology space heat does not mean at all cost flow because in this period of time heat is not needed at all. Also one can see that other energy flowing to environment do not contain any value at all until their application is not found. Difference between cost fluxes which enter and exit particular part of energy system is the cost that is charged to technological product.

2.3. Spending fan [3]

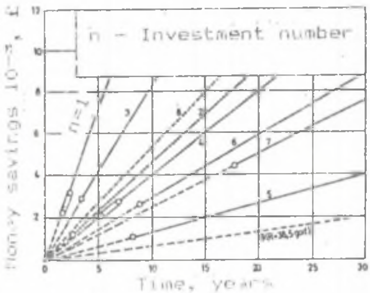

Fig. 3. Saving fan (----- investment is not returned, ——— investment is returned)

Rys. 3. Wachlarz oszczędności (----- nakłady inwestycyjne się nie zwracają, ——— nakłady inwestycyjne ulegają zwróceniu)

In Fig. 3 the spending fan diagram is given. This diagram shows money saving versus time for nine investments in energy system. Dashed lines are parts of these curves where savings are lesser than particular investment values. Full line curves denote cases where money savings are greater than corresponding investment values. Full line curves are separated from dashed lines with dots where investments are equal to savings so time values of this dot present time of return of investment (R). For instance investment #2 has R = 2.5 years, #7 R = = 17.6 years and #9 R = 38.5 years.

3. STEAM-TRAPS

3.1. New steam-trap type rating table [4]

In literature one can find 10 steam-traps and 19 their characteristics rated. But all authors only rate float, bellows and disk steam-traps and they together only take care of mass and size, venting, life and steam loss characteristics. Up to two sources rate reliability at various condensate loads, back pressure performance and sensitivity to dirt, freezing and hydraulic shock. Here one rating table (table 1) out of mean rating data is provided. The worst performances are these of float steam-trap and this of expansion one but there is the lack of data on expansion type of steam-trap. It seems that the best characteristics are these of bimetallic and inverted bucket steam-trap. Good characteristics are of impulse one and instrumented one but there is lack of data on these steam-traps. With these common characteristics rated there are disagreements on performances of different steam-traps (Fig. 4-6). From these figures it can be seen that bimetallic steam-traps would be rated higher if there are not such disagreements about their performances. It seems that there is great degree of agreement that float steam-traps have very bad performances.

Table 1

Rating table obtained through comparison of data of Pajkin, Schmidt and Vallery using non-integer rating method

		Steam trap types									
C	A	M1	M2	M3	S1	S2	S3	D1	D2	D3	I
1	1.1	0.67	0.84	0	1.84	2.83	2	3	2.5	3	0
3	3.2	2	2.5	3	2.25	2.38	1	2.5	1	1.83	2.5
4	4.1	3	3	3	1	2	-	0	2	-	-
6	6.1	1.83	1.5	1.5	2.25	2.33	0	1	2.25	1.5	1.5
8		1.5	2	2	2	1.5	-	0.5	0	-	-
9	9.1	0	0	1	3	2	-	2.5	0	-	-
10		0	1	2	3	0.5	-	3	3	-	-
12	12.1	1.88	2.68	3	2	1.73	1.5	1.67	2.44	1.88	3
13	13.1	2.21	2.5	3	2.05	1.98	2.7	1.2	1.1	1.5	2.7
Specific total ratings		1.45	1.78	2.06	2.15	1.92	1.44	1.71	1.59	1.94	1.94

Note:

Codes for C and A are:

Mass and size - 1, Limitations of mass and size - 1.1, Reliability: different condesate loads - 3, Reliability for periodical condensate load - 3.2, Back pressure perfomance - 4, General back pressure performace - 4.1, Non-condensable venting - 6, General noncondensable venting - 6.1, Sensitivity to dirt - 8, Sensitivity to freezing - 9, General sensitivity to freezing - 9.1, Sensitivity to hydraulic schock - 10, Life - 12, General life - 12.1, Steam loss - 13, General steam loss - 13.1.

Steam-trap types codes are:

Float - M1, Open bucket - M2, Inverted bucket - M3, Bimetallic - S1, Bellows - S2, Expansion - S3, Disk - D1, Orifice - D2, Impulse (piston) - D3 and Instrumented - I.

3.2. Misapplication table [5]

Table 2 is misapplication table for particular steam-trap types: float, open and inverted bucket, bimetallic, bellows, expansion, disk, throttling and instrumented one. Limitations imposed on their use are called critical operating conditions. Float steam-trap has the biggest number of limitations - 12 so one has to be extremaly cautious when use it. After this there are throttling - 9, inverted bucket - 7 and disk steam-trap - 7. There are no big limitations for applicability of instrumented - 4, bellows - 4, bimetallic - 3 and expansion one - 1. This misapplication table obtained by literature data gathering enable us to make possible applicability diagnosis of every steam-trap type placement with greater confidence than if this diagnosis is based on only one steam rating table out of only one literature source. Such an analysis should be recommended in the

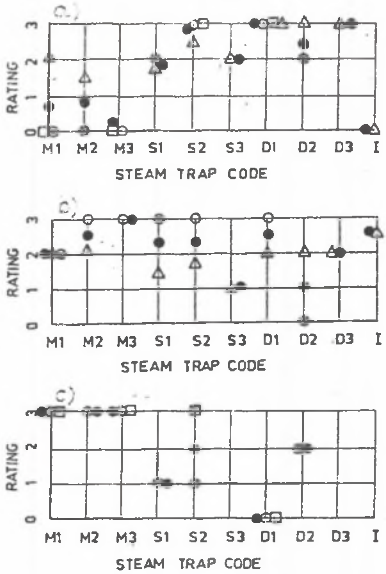

Fig. 4. Ratings for different steam-trap types:

a) mass and size, b) reliability at periodical condensate load, c) back pressure performance. ○ Pajkin, □ Schmidt, △ Vallery, ● average ratings

Rys. 4. Znamiona różnych typów pułapek parowych:

a) masa i wymiar, b) niezawodność przy periodycznym obciążeniu kondensatem, c) wartość ciśnienia powrotnego. ○ Pajkin, □ Schmidt, △ Vallery, ● znamiona średnie

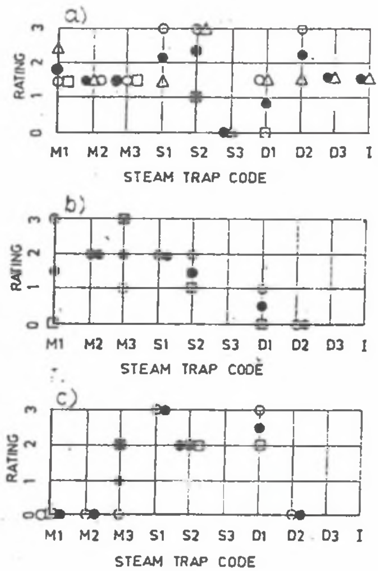

Fig. 5. Ratings for different steam-trap types:

a) noncondensable venting, b) dirt sensitivity, c) freezing sensitivity. ○ Pajkin, □ Schmidt, △ Vallery, ● average ratings

Rys. 5. Znamiona różnych typów pułapek parowych:

a) niekondensujące odpowietrzanie, b) wrażliwość na zanieczyszczenia, c) wrażliwość na zamarzanie, ○ Pajkin, □ Schmidt, △ Vallery, ● znamiona średnie

stage of designing, construction and exploitation of steam-trap systems so investment steam-trap losses so as subsequent steam and production ones can be avoided.

3.3. Multiple steam misapplication influence [5]

This study reveled the existence of multiple steam-trap misapplication influence other then single one on the steam and condensate system. We examined steam and condensate system in garment industry (Fig. 7) with steam-trap types which satisfy misapplication table 2. Some practical cases of steam-trap type misapplication from industry are investigated in order to find out consequences of these for steam and condensate system.

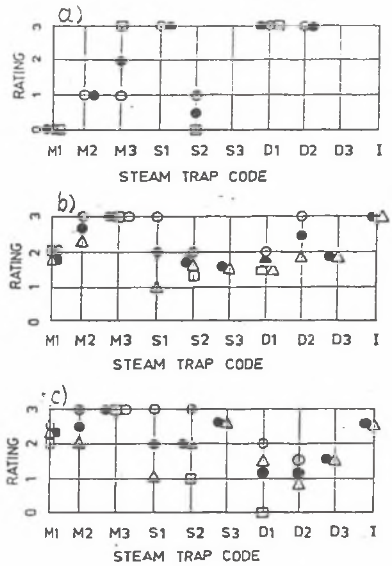

Fig. 6. Ratings for different steam-traps:
a) sensitivity ratings to hydraulic shock, b) steam-trap life, c) steam loss. ○ Pajkin, □ Schmidt, △ Vallery, ● average rating

Rys. 6. Znamiona różnych pułapek parowych:
a) stopień wrażliwości na uderzenie hydrauliczne, b) żywotność pułapek parowych, c) straty pary. ○ Pajkin, □ Schmidt, △ Vallery, ● znamiona średnie

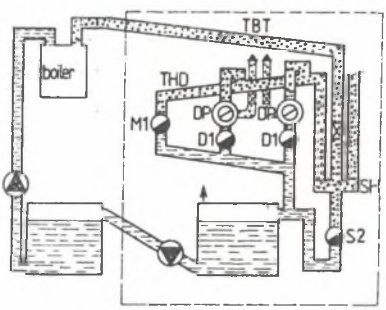

Fig. 7. Basic steam and condensate system in garment industry

Rys. 7. Podstawowy system pary i kondensatu w przemyśle odzieżowym

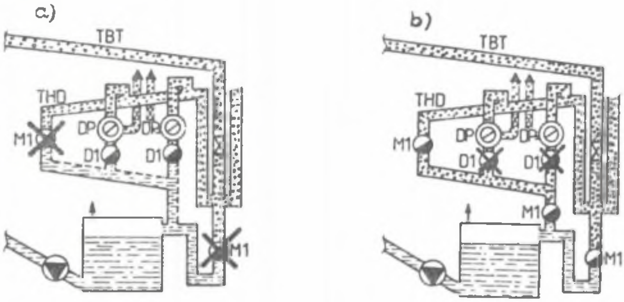

Fig. 8. Energy spending part of steam and condensate system in garment industry:

a) hydraulic shock case, b) back pressure case

Rys. 8. Cząstkowe zużycie pary i kondensatu w przemyśle odzieżowym

a) przypadek uderzenia hydraulicznego, b) przypadek wzrostu ciśnienia powrotnego

Table 2

Critical application conditions for particular steam trap types: misapplication - 0, possible application - 1

Code C	A	Ref. 2	Ref. 3	Ref. 4
1	2	3	4	5
a)	Float steam trap			
1.1.	Mass and size:limitation	0	-	1
2.1.	Assembly space orientation: unproper	0	-	-
5	Undercooled condensate removal			
5.1	Undercooled for 30°C	0	-	-
5.2.	Requlated undercooling	0	-	-
7.1	Dirt: yes	1	0	-
8.	Sensitivity to freezing			
8.1	Automatic removal of water	0	0	-
9.1	Hydraulic schock: yes	0	0	-
10.1	Return flow: yes	0	-	-
12	Heat loss	0	-	-
13	Cost			
13.1	Small condensate load	-	-	0
13.2	Medium condensate load	-	-	0
13.3	Large condensate load	-	-	0

cd. tablicy 2

1	2	3	4	5
b)	Open and inverted bucket steam trap			
1.1	Mase and size: limitations	0	0^{M3}	0^{M2}
2.1	Assembly space orientation: unproper	0	-	-
5	Undercooled condensate removal			
5.1	Undercooled for 30°C	0	-	-
5.2	Regulated undercooling	0	-	-
8	Sensitivity to freezing			
8.1	Automatic removal of water	0	1	-
10.1	Return flow: yes	0	-	-
12	Heat loss	0	-	-
c)	Bimetallic steam trap			
13	Cost			
13.1	Small condensate load	-	-	0
13.2	Medium condensate load	-	-	0
14	Condensate load applicability			
14.3	Large condensate load	-	-	0
d)	Bellows steam trap			
9.1	Hydraulic schock: yes	1	0	-
13	Cost			
13.1	Small condensate load	-	-	0
14	Condensate load applicability			
14.2	Medium condensate load	-	-	0
14.3	Large condensate load	-	-	0
e)	Expansion steam trap			
13	Cost			
13.1	Small condensate load	-	-	0
f)	Disk steam trap			
3	Reliability: different condensate loads			
3.3	Light condensate load	1	0	-
4	Back pressure perfomance			
4.1	More than 70% of enterance pressure	0	0	-
5	Undercooled condensate removal			
5.1	Undercooled for 30°C	0	-	-
5.2	Requlated undercooling	0	-	-
6.1	Vacuum use: yes	0	-	-
7.1	Dirt: yes	1	0	-
11	Steam loss			
11.1	General	1	0	1

c.d. tablicy 2

1	2	3	4	5
g)	Throtling steam trap			
3	Reliability: different condensate loads			
3.1	Periodical condensate load	0	-	-
3.2	Large start up condensate load	0	-	-
3.3	Light condensate load	0	-	-
5	Undercooled condensate removal			
5.1	Undercooled for 30°C	0	-	-
5.2	Regulated undercooling	0	-	-
7.1	Dirt: yes	0	-	-
8	Sensitivity to freezing			
8.1	Automatic removal of water	0	-	-
11	Steam loss			
11.1	Periodical condensate load	0	-	-
11.2	Light condensate load	0	-	-
h)	Instrumented steam trap			
1	Mass and size: limitations	-	-	0
13	Cost			
13.3	Large condensate load	-	-	0
14	Condensate load applicability			
14.1	Small condensate load	-	-	0
14.2	Medium condensate load	-	-	0

In the first misapplication case condensate is taken away from steam header by M1 type of steam-trap (Fig. 8a) subjected to return flow conditions. This flow conditions damaged this steam-trap of steam header and downstream water hammer conditions were produced so as mechanical failures of these steam-traps downstream as M1 steam-trap type which are sensitive to these influences. This will make additional operation costs.

In the second misapplication experiment new M1 steam-trap (group trapping) was put downstream of D1 (particular trapping) steam-traps of steam devices and M1 steam-trap of steam transportation pipe (Fig. 8b). These new steam-trap formed back pressure influence upstream to old particular steam devices trape and these of header-devices transportation pipe and D1 steam-traps will not function and stand open. This will not risk industrial production but only one kind of steam-trapping is sufficient in order steam and condensate system to function properly so another one is for sure investment loss. Maintenance must be aware of it because of large investment loss scale with respect to single misapplication influence loss.

4. CONCLUSION

For an industrial building of garment industry energy flow diagram is found. It is found that degraded energy partially satisfied heating winter needs lowering hot wated heating costs and partially induced electrical energy spending.

Energy cost flow for this building revealed that degraded technology energy in the case of unnesessary non-insulated surfaces of technological plates and pipes makes cost losses if this energy satisfied heating energy needs in winter.

Investment fan diagram is very useful for graphical comparison of different energy savings possibilities.

Joint steam rating table from different reference sources showed that worst steam-trap is float and the best bimetallic one but there is lot of different opinions on steam-traps performances. Anyway it is necessary to do more rating job so practical engineer can have more data he can relay on.

Steam-trap type misapplication table gives series of critical operating conditions for different steam-traps. Again, one should be very cautious when float steam-trap is applied.

Two practical misapplication cases are investigated. It is found that application of float steam-trap in return conditions leads to water hammer influences downstream of misapplied steam-trap and to additional operation costs. Group trappings when particular trapping already exists makes upstream back pressure conditions leading to investment losses. So some usual practice in industry can be very dangerous and engineers in industry must prevent them.

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SYSTEMY ENERGETYCZNE W PRZEMYSLE: BUDYNKI PRZEMYSŁOWE I RODZAJE PUŁAPEK PAROWYCH

S t r e s z c z e n i e

W pracy podano rezultaty badań pewnego systemu energetycznego w przemyśle odzieżowym. Sporządzono pasmowy wykres strumieni energii oraz związanych z nimi strumieni kosztów. Wykazano, że wykorzystanie energii niskotemperaturowej nie zawsze prowadzi do oszczędności energetycznych i ekonomicznych. Szczególną uwagę zwrócono na pułapki parowe zawarte pomiędzy obszarami parowymi i wodnymi.

ЭНЕРГЕТИЧЕСКИЕ СИСТЕМЫ В ПРОМЫШЛЕННОСТИ: ПРОМЫШЛЕННЫЕ ЗДАНИЯ И РОДЫ ПАРОВЫХ ЛОВУШОК

Р е з ю м е

В работе представлены результаты исследований энергетической системы в швейной промышленности. Составлено полосные диаграммы потока энергии а также связаны с ними потоки росходов. Предъявлено, что использование низкотемпературной энергии не всегда ведет к энергетическим и экономическим свережениям. Особое внимание обращено к паровым ловушком заключеным между водными и паровыми пространствами.