SPX

EDITORIAL

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Case Study – Condenser expertise from SPX focuses maintenance where it's needed and cuts downtime to a minimum to restore production to full capacity

Introduction

Low production was causing headaches for the maintenance crew at a peptone concentration plant – the complex interaction of the condenser, the cooling tower and the vacuum pump meant that there were several possible causes. The suggestion to take the entire system off line for a couple of days to check and service every part was not well received by the plant manager. What to do ?

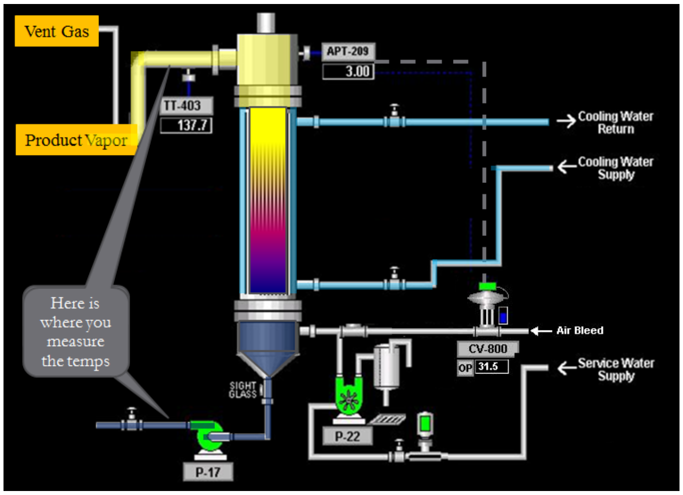
Result

Discussing the problem with SPX provided an alternative approach. Based on many years of experience and hundreds of condensers installed in a huge variety of applications worldwide, SPX has developed a series of simple tests to narrow down the causes of underperforming condensers which allow maintenance efforts to be focused where they are most needed, restoring full production capacity, and, most importantly, getting the plant back on line in the shortest possible time. The first test can be carried out in just two minutes with the plant in full operation.

A proven methodology for checking condenser performance

To carry out the first test, make sure that everything is running as normal, namely, the condensate pump is actually pumping condensate out, the cooling tower is working with the fans on, and the cooling water circulation pump is pumping.

Now simply use an infra-red (IR) scanner to measure the vapor duct temperature entering the condenser and then scan the condensate discharge line from the condenser as shown here.



Note that an IR scanner requires a dull surface to measure correctly; a reflective surface such as stainless steel will give false readings. It is enough to put some masking tape on the pipe and scan the tape.

The condensate temperature should be some 30°F (16°C) cooler than the product vapor inlet temperature. If this is the case, then it is a false alarm - the condenser is working well, but it is always wise to treat the cooling tower water for minerals, especially if the plant uses well water, to make sure the condenser does not become fouled.

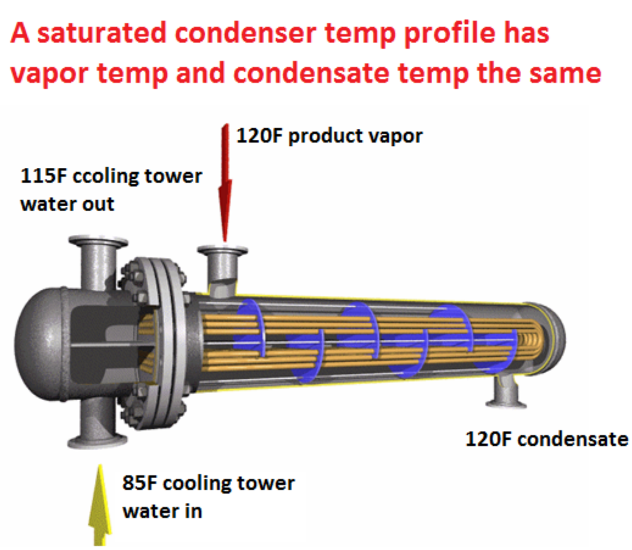
If the two scanned areas are at approximately the same temperature then the test confirms that the condenser is not operating as it should. It is what is termed “saturated" and the methodology outlined below should be followed to isolate the cause.

So why does this simple test reveal so much?

To understand the test, it helps to understand a little more about the principles of operation of a condenser. Located at the end of the evaporation process after the last effect, the condenser receives the product vapors being boiled off in the last separator vessel and uses a flow of cooling water to cool them so that all the vapor is condensed into a liquid that is then removed by the condenser’s condensate pump. The heat, now carried by the cooling water, then passes to the cooling tower so it can be dissipated to the atmosphere. SPX primarily uses two types of condensers to do this, the Tubular (horizontal or vertical) and the Plate and Frame, both use the same principle of operation and the procedures outlined here apply equally to both.

The two sides of the condenser, the vapor side and the cooling medium side, allow heat to be transferred between the two while keeping them physically apart. In a tubular type, tubes housed inside an outer shell, the vapors may be on the tube side and cooling medium on the shell side however this could also be the other way around depending on the process. In a plate type, the two media are separated by a set of plates. In both types, the hot vapors come into contact with surfaces which are kept cool by the cooling medium (the water from the cooling tower) and condense into water, termed condensate.

Because the medium entering the condenser is vapor, the latent heat of vaporization must be removed to produce the condensing effect (change of state) and the temperature cannot be reduced until this heat is removed. It is a large amount; approximately 970 BTU’s per pound of steam (2257 kJ/kg) just to change the vapor state into water at the same temperature. See the example below :



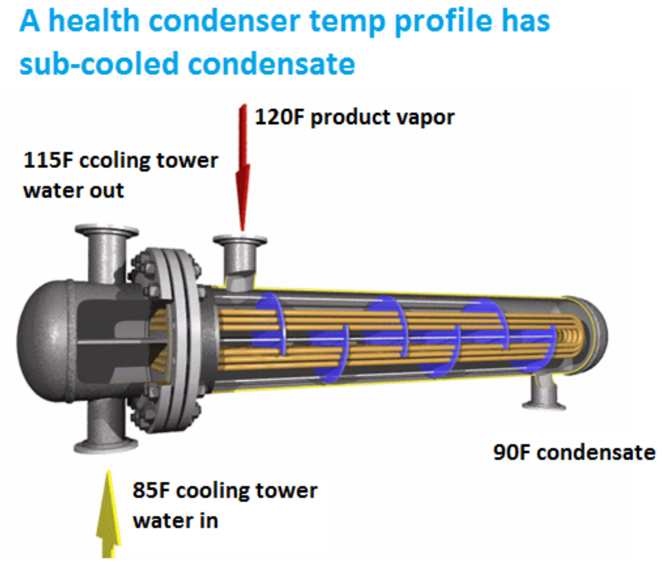
The temperature of the condensate can only fall below the vapor temperature of 120F (48°C) when all vapor in the condenser has changed into a liquid. That is termed sub-cooling and is the correct mode of operation for the condenser. IT IS IMPORTANT TO UNDERSTAND THIS.

If the condenser is not sub-cooling, insufficient heat is being removed and temperatures will rise, giving low capacity and/or low product concentration.

In ideal conditions, if the incoming vapor is at 120F (48°C) and the cooling tower is delivering water at 85F (29.5°C), the cooling water should leave the condenser about 15F (8°C) hotter due to the heat it has absorbed from the vapor. Theoretically the sub-cooling of the condensed vapors could go as low as 85F (29.5°C). However that is a little unrealistic, in practice the condensate should exit the condenser at a temperature somewhere between the cooling water inlet temperature of 85F (29.5°C) and the exiting water temperature of 100F (38°C).

That is how the simple test works - if the condensate temperature is at or close to the vapor temperature coming from the last effect separator vessel, the condenser is underperforming – it is saturated.

Here is an example of a well performing condenser displaying 120F (48°C) vapor sub-cooled to 90F (32°C) condensate, that is 30F (16°C) of sub-cooling.



What are the causes of low or no sub-cooling effect?

Fouling. In most cases the cause is fouled surfaces in the condenser which reduce heat transfer and so increase the temperature gradient across the condenser. Most commonly, it will be the cooling tower water that has fouled the condenser. Cooling towers need to be treated not only with biocides but also for minerals like silica which form on the surface of the condenser, rather like a domestic hot water tank.

If this is the problem, the cooling tower must be isolated from the condenser and the condenser cleaned with acid to break down the scale. Dilute acid can be circulated with a portable pump from a large drum similar to the process used to clean boiler tubes. Once restored, use a preventative treatment for mineral scale.

TEMPERATURE		PRESSURE		VACUUM	
°F	°C	PSIA	BAR	In Hg	mm Hg
100	37.778	0.94924	0.06546	27.989	1.93028
101	38.333	0.97818	0.06746	27.930	1.92621
102	38.889	1.00789	0.06951	27.869	1.92200
103	39.444	1.03838	0.07161	27.807	1.91772
104	40.000	1.06965	0.07377	27.743	1.91331
105	40.556	1.10174	0.07598	27.678	1.90883
106	41.111	1.1347	0.07826	27.611	1.90421
107	41.667	1.1684	0.08058	27.542	1.89945
108	42.222	1.2030	0.08297	27.417	1.89083
109	42.778	1.2385	0.08541	27.400	1.88966
110	43.333	1.2750	0.08793	27.325	1.88448
111	43.889	1.3123	0.09050	27.249	1.87924
112	44.444	1.3505	0.09314	27.172	1.87393
113	45.000	1.3898	0.09585	27.092	1.86841
114	45.556	1.4299	0.09861	27.001	1.86214
115	46.111	1.4711	0.10146	26.926	1.85697
116	46.667	1.5133	0.10437	26.840	1.85103
117	47.222	1.5566	0.10735	26.752	1.84497
118	47.778	1.6009	0.11041	26.662	1.83876
119	48.333	1.6463	0.11354	26.569	1.83234
120	48.889	1.6927	0.11674	26.475	1.82586
121	49.444	1.7403	0.12002	26.378	1.81917
122	50.000	1.7891	0.12339	26.279	1.81234
123	50.556	1.8390	0.12683	26.177	1.80531
124	51.111	1.8901	0.13035	26.073	1.79814
125	51.667	1.9428	0.13399	25.966	1.79076
126	52.222	1.9959	0.13765	25.858	1.78331
127	52.778	2.0507	0.14143	25.746	1.77559
128	53.333	2.1068	0.14530	25.632	1.76772
129	53.889	2.1642	0.14926	25.515	1.75966
130	54.444	2.2230	0.15331	25.395	1.75138
131	55.000	2.2830	0.15745	25.273	1.74297
132	55.556	2.3445	0.16169	25.148	1.73434
133	56.111	2.4074	0.16603	25.020	1.72552
134	56.667	2.4717	0.17046	24.889	1.71648

Hot Tower Water. In general the cooling tower should provide 85F (29.5°C) water to the condenser during the hottest days of summer. If this is not the case and the temperatures are higher, the tower is saturated and is not transferring the heat to the atmosphere. Check the fans, motor direction and spray nozzles if both inlet and outlet temperatures are abnormally high.

If the tower water temp to the condenser is normal but the outlet temp is abnormally high (a greater than 15F [8°C] rise) then this indicates low flow from the cooling water pump. Logically if the water is moving slower it has more residence time, gains more heat and the temperature rises.

Vacuum and its role. The system design temperature typically requires the last effect to operate at 120F (48°C) and this requires a vacuum of at least 26.5"Hg or 1.7 PSIA (12kPa). (These design temperatures are shown in the system PID. Given the project number, SPX can supply a copy from their archives).

To test the vacuum, start the evaporator, circulate water, and start pulling vacuum with no steam applied. If, after 20 minutes, the vacuum is only around 25.4"Hg or 2.2 PSIA (15kPa), then there are leaks. This means that when steam is applied, the last effect will run hot regardless of the condenser performance. This is simply the temperature - pressure relationship of saturated steam as shown in the table. In this case, you must address the leaks as the problem is not in the condenser.

Conclusion

Using this methodology, once it has been confirmed by the initial test that the condenser is saturated, it is possible to narrow down the cause quickly and effectively so that maintenance can be focused optimally and the plant restored to correct operation in the shortest time possible.

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