

Sudan University of Science and
Technology
College of Graduate Studies

Study of Pressure drop in Heat
Exchangers

**A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in
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Prepared by:

Eng. Amir AbuBakr Musa

Supervised by:

Prof. William Ibrahim Assad

Verse

قال تعالى:

(رَبِّ اشْرَحْ لِي صَدْرِي
وَاحْلُلْ عُقْدَةً مِنْ لِسَانِي
وَيَسِّرْ لِي مَآرِجِي
يَفْقَهُوا قَوْلِي

صدق الله

العظيم

سورة طه

Dedication

This research is dedicated to

My parents with great love

My friends

And my colleagues

Eng. Amir AbuBakr

Abstract

Heat exchangers are frequently used in industry especially in steam and gas turbines power plants, as air pre-heaters or economizers and the like. These are mainly used to recover part of the thermal energy in exhaust and flue gases.

The measure of performance of these equipments is usually given as a heat ratio which is a measure of the heat recovered from the exhaust. Heat exchangers suffer from pressure losses due to the resistance to fluid flow through the passages on both sides of the exchanger. The pressure drop means in most cases, a loss in the useful work output.

In this research the investigation concentrates on the thermal ratio and the pressure drop in heat exchangers applied in existing power stations. Three of the largest power stations in Sudan are examined: namely:

- i. Khartoum Refinery Company (at Elgili).
- ii. Khartoum North Thermal Power Station.
- iii. Kenana Sugar Factory.

Temperatures and pressures were measured and calculations were carried out and the results were presented, and discussed.

Kern methods for calculating the pressure drop were examined using data obtained from unit (2) phase (I) in Khartoum North thermal power station.

The results obtained revealed that:

- a) The thermal ratio of heat exchangers, in addition to their dependence on the thermal properties of the material from which they are made,

was affected by the method of design and the inlet conditions. The results of the tests showed that for the shell and tube type of heat exchanger used in Kenana Sugar Factory, the thermal ratio was 0.52 while it was about 0.777 for the rotary heat exchanger used in Khartoum North thermal power station, phase (II) unit (4).

- b) The least pressure drop amounting to about (190 pa) i.e. about 1.6% of the inlet pressure, when using bar heaters as in Khartoum Refinery Company, and the highest pressure drop was (1830 pa) i.e. about 7.7% of the inlet pressure drop, when using Rotary heat exchangers, as in phase (II) unit (4) of Khartoum North thermal power station.

الخلاصة

المبادلات الحرارية تستخدم كثيراً في الصناعة خاصةً في محطات القدرة الغازية والبخارية، كما في سخانات الهواء قبل الاحتراق ووحدات الاقتصاد وما شابه، هذا بشكل رئيسي تستعمل لاستعادة جزء من الطاقة الحرارية في غازات المدخن والعام.

قياس الأداء لهذه الأجهزة عادة يقدر بالنسبة الحرارية التي تحدد للمبادل الحراري كمية الحرارة المستعادة من العام. لكن المبادلات الحرارية يصاحبها هبوط الضغط بسبب المقاومة التي تعوق تدفق الموائع خلال الممرات على جانبي المبادل. هبوط الضغط، تقريباً في كثير من الحالات يقلل من ناتج الشغل المستفاد.

في هذا البحث، يركّز التحقيق على النسبة الحرارية وهبوط الضغط في المبادلات الحرارية المستخدمة في ثلاث من محطات القدرة في السودان وهي:

- i. شركة مصفاة الخرطوم (أليجلي).
- ii. محطة توليد الخرطوم بحري الحرارية.
- iii. مصنع سكر كنانة.

لقد تم قياس وحساب درجات الحرارة والضغط ، و عرضت النتائج. ثم استعملت طريقة (Kern) لحساب هبوط الضغط باستعمال القراءات التي تم الحصول عليها من الوحدة (2) المرحلة (II) في محطة الخرطوم بحري الحرارية.

جملة النتائج التي حصلت هي:

أ). النسبة الحرارية للمبادلات الحرارية، بالإضافة إلى اعتمادها على الخواص الحرارية للمواد التي صنعت منها، تتأثر بالشكل التصميمي وحالة الموائع عند المدخل. إنّ نتائج الاختبارات أعطت للمبادل الحراري ذو الأنبوب والغلاف من المبادلات الحرارية المستعملة في مصنع سكر كنانة، النسبة الحرارية حوالي 0.52 ، بينما حوالي 0.777 للمبادل الحراري

الدّوار المستعمل في محطة توليد الخرطوم بحري الحرارية، المرحلة (II) الوحدة (4).

ب). حيث بلغ أقل هبوط للضغط حوالي (190 باسكال) أي بنسبة حوالي 1.6% من قيمة الضغط عند المدخل، وذلك عند استعمال مبادلات القضبان الحرارية كما في شركة مصفاة الخرطوم، بينما يبلغ أعلى هبوط للضغط حوالي (1830 باسكال) أي بنسبة حوالي 7.7% من قيمة هبوط ضغط عند المدخل، وذلك عند إستعمال المبادّل الحراري الدّوار، كما في المرحلة (II) وحدة (4) في محطة توليد الخرطوم بحري الحرارية.

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Nomenclature

| Symbol | Quantity | Coherent SI Unit |
|------------|-------------------------------------|--------------------------|
| ΔP | Total pressure drop | $N/m^2 = kg/(m.s^2)$ |
| D | Tube inside diameter | m |
| U | The main velocity | m/s |
| u | Velocity, velocity component | m/s |
| P | Pressure | $N/m^2 = kg/(m.s^2)$ |
| P | Tube pitch | m |
| A | Surface area | m^2 |
| S | Cross-sectional area | m^2 |
| r_o | Outer tube radius | m |
| f_o | Friction factor | -- |
| D_h | Hydraulic diameter | m |
| η | Viscosity | $(N.s)/m^2 = kg/(m.s)$ |
| λ | Thermal conductivity | $W/(m.K) = (kg.m)/s^3.K$ |
| t | Thickness | m |
| ρ | Density | kg/m^3 |
| K_a | Inlet factor | -- |
| V_{max} | Maxim. fluid velocity between tubes | m/s |
| α | Overall heat transfer coefficient | $W/(m^2.K)$ |
| η_w | Water viscosity | $(N.s)/m^2 = kg/(m.s)$ |

| | | |
|-----------------|---|--------------------------|
| ΔT_{LM} | Logarithmic mean temperature difference | K |
| ΔT | Temperature difference | K |
| δ | Boundary layer thickness | m |
| δ | Thickness, liquid film thickness | m |
| ΔP_s | Shell side pressure drop | $N/m^2 = kg/(m.s^2)$ |
| C_p | Specific heat capacity at constant pressure | $J/(kg.K) = m^2/(s^2.K)$ |
| m | Mass flux (mass velocity) | $kg/(m^2.s)$ |
| M | Mass flow rate | kg/s |
| n_r | Number of tubes in rows | -- |
| ΔP_c | Cross – flow pressure drop | $N/m^2 = kg/(m.s^2)$ |
| n_t | Number of tubes in column | -- |
| C' | Tube clearance | m |
| N | Number of baffle plate | -- |
| N_T | Number of tubes | -- |
| D_e | Equivalent diameter | m |
| D_s | Shell inside diameter | m |
| S_s | Factor | -- |
| L_b | The baffle spacing | m |
| P_T | Tube pitch | m |
| L_B | The distance between baffles | m |
| ΔP_w | The windows zone pressure drop | $N/m^2 = kg/(m.s^2)$ |
| S_m | Flow area near the center | m^2 |
| D_{OTL} | The tube bundle diameter | m |
| L_c | The baffle cut distance | m |
| S_{sb} | Shell-to baffle leakage area | m^2 |
| S_{st} | Tube-to baffle leakage area | m^2 |
| δ_{st} | The radial clearance between tube and baffle | m |
| δ_{sb} | The radial clearance between shell and baffle | m |
| N_c | Number of cross rows | -- |
| S_w | Window flow area | m^2 |

| | | |
|----------|--|----|
| P_{TP} | Spacing between tube rows in flow direction | m |
| D_w | Equivalent diameter in windows zone | m |
| R_B | Correction factor for the influence of bypass | -- |
| R_L | Correction factor for the influence of leakage | -- |
| N_{cw} | Number of effective cross-flow rows in window zone | -- |

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