NEW CHIMNEY DESIGN

Gains from use od a diffuser

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Hadek Company developed with the support of the Expert Office Exponent a new chimney type based on the concrete windshield protected by a Pennguard™ lining. The technology denoted as the New Chimney Design (NCD) had been used in power stations in many countries. Due to this success Hadek commissioned to Exponent a new study on gains from the use of a diffuser. The results prove that the flue gas draft can be substantially increased without an increase in the overall cost.

NCD CHIMNEYS

Development of NCD, [02, 03, 06, 08, 10, 11]

The chimney type was developed by the Hadek Company with the support of the Expert Office Exponent in 1998 [3]. The major characteristic of the art is that there is no independent internal flue, but the windshield is protected by a Pennguard™ lining stuck to its internal face. Such chimneys, denoted as the New Chimney Design (NCD), have been built in power stations all over the world under a variety of operation scenarios, among other wet stack operations. Due to the growing success of the NCD Chimneys, Hadek commissioned to Exponent the following additional studies.

- Further development of the NCD chimneys [10]
- Long term performance of the NCD chimneys [02]
- Gains from use of a diffusor for the NCD chimneys [11], basis for this paper
- Necessity of a highly qualified structural design for the NCD chimneys [12]

Arrangement and Standing, Fig. 1, [02, 03, 06, 08, 10, 11]

The high-tech NCD-chimneys earn the following assessment [08, 10]:

- lack of internal components such as independent flues, support slabs and corbels
- universal in use in terms of the modern wet stack operation
- economic in terms of the overall costs,
- reliable, simple and durable in operation.

Hence such chimneys are built all over the world under a variety of operation scenarios. However, due to their slenderness and higher temperature an advanced design by qualified experts is needed [12].

Targets of the Study [11]

The NCD chimneys are suitable for the modern wet stack operation where flue gases are cold, wet and heavy. In such cases due to the insufficient natural chimney draft special fan boosters are required. However, such a measure is expensive and this is why Hadek had decided to prove if fan boosters can be replaced by chimney diffuser. Following this idea, the targets of the study [11] were as follows:

- Which sort of diffuser can sufficiently increase the flue gas underpressure?
- What are the costs of such a measure?

DIFFUSER BASICS

Determination of the Underpressure, Figure 2, [01]

The diffusor efficiency Δp_w obeys the given equations which result from the low of the Energy Conservation regarding

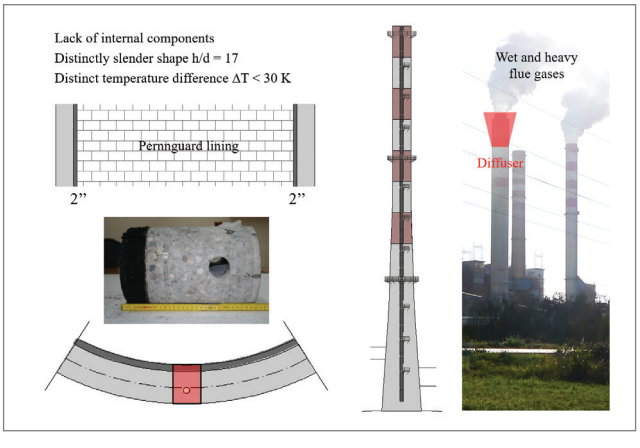

Figure 1: Structure arrangement of NCD Chimneys

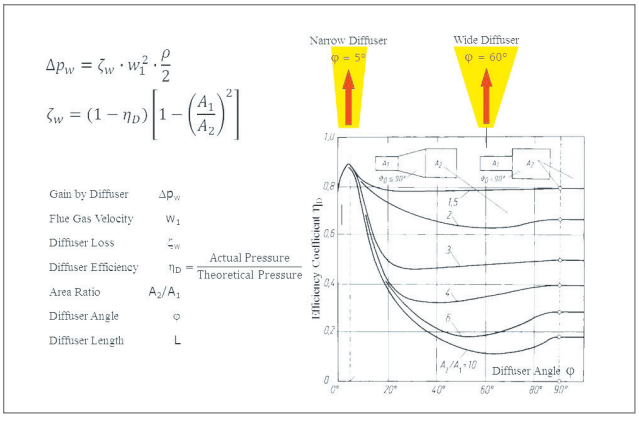

Figure 2: Diffuser basics Computation bases for the gain in underpressure by diffuser

pressure, potential and kinetic energy [01]. It is governed by the following magnitudes:

Flue Gas Velocity	w_1
Diffuser Efficiency	η_D
Area Ratio	A_2/A_1
Diffuser Angle	φ
Diffuser Length	L

The study indicates that the most sensible diffuser angle amounts to 8°. Larger angles produce flue gas turbulences which cause a large decrease of the diffuser efficiency down to 0.1.

Way Diffuser Works, Fig. 3, [01, 11]

The goals of the diffuser application are as follow:

- Avoiding flue gas overpressure especially in case of wet and heavy flue gases
- Keeping low operation costs in terms of going without flue gas heating and fan boosters

The diffuser effect can be described as follows:

- Basic flue gas underpressure of 186 Pa is created at the chimney bottom due to its height
- Formation of an additional underpressure of 110 Pa takes place at the chimney top due to diffuser
- This gain of 110 Pa is kept up within the entire chimney height

In this way the draft gain formed at the very top determines the behavior of the entire chimney.

DIFFUSER STUDY

Investigation Bases, Fig. 4, [11]

The study [11] was carried out for the operation conditions diffuser features given in Fig. 4.

Results of the Study, Fig. 5, [11]

The study reveals the following rules regarding the flue gas underpressure:

- Internal diameter
  D – Underpressure decrease with growing diameter
- Diffuser angle
  φ– Underpressure maximum at around 8°
- Diffuser length
  L – Underpressure increase with growing length

Diffuser Efficiency, Fig. 5, [11]

The computation results provide the following gains in underpressure:

- No Diffuser L = 0 m (186 Pa)
- Diffuser length L = 5 m (+ 37 %)
- Diffuser length L = 10 m (+ 53 %)
- Diffuser length L = 15 m (+ 61 %)

This simply proves that for the investigated case

- Chimney height H = 150 m
- Internal diameters D = 8 m
- Amb. temperature T_A = 15°C

The best diffuser efficiency is gained at the following diffuser features:

- Diffuser angle φ = 8°
- Diffuser length L = 15 m

These result are also valid for the remaining two internal diameters of 6.0 m and 10.0 m.

WINDSHIELD STUDY

Investigation Bases, [04, 05, 07, 09]

The study was carried out for the following chimney features:

Materials	S500, C25/30
Height	150 m
Internal Diameter	D = 6m / 8m / 10m
Diffuser Length	L = 5m / 10m / 15m
Wind Load	Zone II, Europe

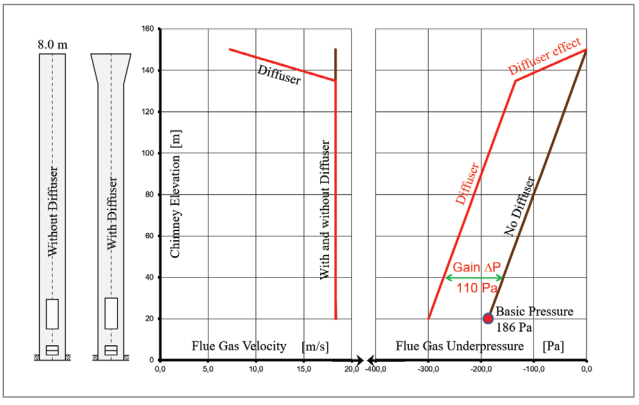

Figure 3: Diffuser effect

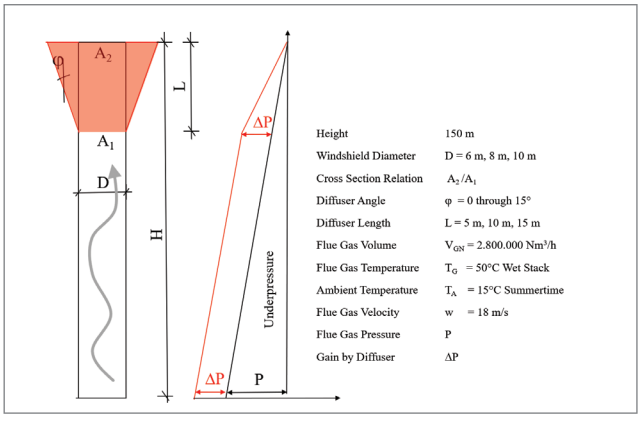

Figure 4: Investigation Bases of diffuser study

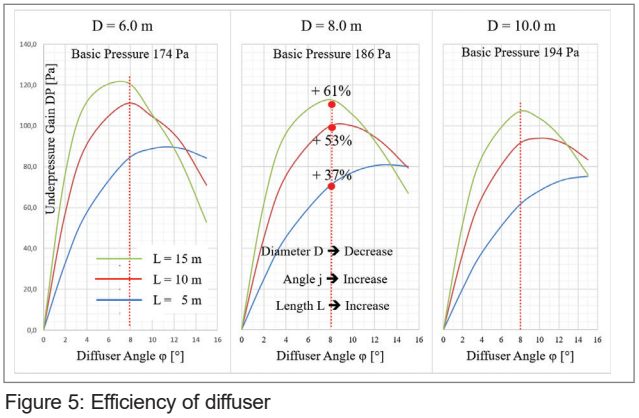

Figure 5: Efficiency of diffuser

Results of the Study, Fig. 6

The results for the chimney H = 150 m, D = 8.0 m and L = 15 m contain the following values:

• Dimensions	Diameter d, wall thickness t, vertical reinforcement ρ
• Wind load	q = 1.22 kN/m² at the very top
• Cross sect. forces	Moments M, 2nd order moments M^{II}, normal force N
• Strains	Steel ε_s, concrete ε_c < 2.00 ‰
• Deflections	q = 2.11 m at the very top

The results prove that the presence of the diffusers hardly changes the chimney strains. The only affected cost position is formwork which is by 40% higher in case of chimneys with diffuser.

Material consumption

The investigation results prove that the diffuser length hardly affects the material consumption

- Formwork: substantial increase due to the conical diffuser shape

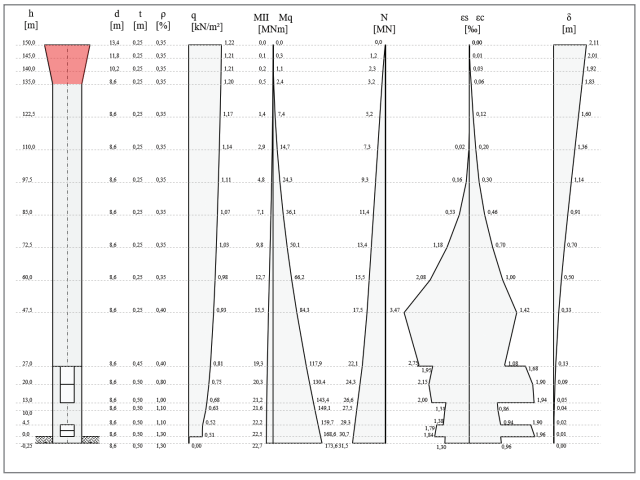

Figure 6: Results of the windshield study

- Windshield: tiny increase due to the diffuser length
- Lining: no change
- Foundation: no change

GAINS VS. COSTS

Findings

The investigations resulted in the following numbers:

	No Diffuser	L = 5.0 m	L = 10.0 m	L = 15.0 m
Gains in underpressure	186 Pa	+ 37%	+ 53%	+ 61%
Overall costs	5.03 Mio €	+ 5%	+ 6%	+ 7%
Lining	2.30 Mio €	2.31 Mio €	2.33 Mio €	2.35 Mio €
Site Facilities	0.18 Mio €	0.18 Mio €	0.18 Mio €	0.18 Mio €
Formwork	0.64 Mio €	0.84 Mio €	0.86 Mio €	0.87 Mio €
Windsshield	1.60 Mio €	1.61 Mio €	1.63 Mio €	1.66 Mio €
Foundation	0.31 Mio €	0.31 Mio €	0.31 Mio €	0.31 Mio €

Conclusions

The investigation results prove that the gain in underpressure of +61% due to the diffuser towers decisively above the corresponding cost increase of only +7%. This had been reached by the following optimal diffusor arrangement:

- Diffuser angle $\varphi = 8°$
- Diffuser length $L = 15$ m

This finding is valid for chimneys of around 150m height and with diameters of 6.0 m, 8.00 m and 10.0 m.

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Abstract: NEW CHIMNEY DESIGN, GAINS FROM USE OF A DIFFUSER. Hadek Company developed with the support of the Expert Office Exponent a new chimney type based on the concrete windshield protection by a Pennguard™ lining. The technology denoted as the New Chimney Design (NCD) had been used in power stations in many countries. Due to this success Hadek commissioned to Exponent a new study on gains from the use of a diffuser. The results prove that the flue gas draft can be substantially increased without an increase in the overall cost.

Key words: industrial chimneys, flue gas pressure, diffuser, protection against flue gas

Streszczenie: NEW CHIMNEY DESIGN, KORZYŚCI ZE STOSOWANIA DYFUZORA. Firma Hadek stworzyła przy pomocy biura eksperckiego Exponent nowy typ komina wykorzystującego ochronę trzona wykładziną Pennguard™. Technologia ta, nazwana New Chimney Design (NCD), jest stosowana w elektrowniach w wielu krajach świata. W obliczu sukcesu Hadek zlecił Exponent nowe badania dotyczące korzyści z aplikacji dyfuzora. Wyniki tych badań dowodzą, że podciśnienie spalin może być znacząco podwyższone bez wzrostu ogólnych kosztów konstrukcji.

Słowa kluczowe: kominy przemysłowe, ciśnienie spalin, dyfuzor, zabezpieczenie przed spalinami.