Environment Protection Engineering

Vol. 18 1992 No. 3–4

HENRYK MELOCH*, PIOTR KABSCH*

INJECTION SCRUBBERS – STATE OF KNOWLEDGE AND APPLICATIONS

The paper presents advantages of injection scrubbers designed for cleaning of waste gases. The advantages are considered on the background of the tendencies towards simplification of construction and better reliability of apparatus. The investigations that have hitherto been carried out in order to describe the processes, which occur in injection scrubbers, and problems encountered in the course of their designing are discussed. Some examples of injection scrubbers designed by the authors in the commercial scale or in a pilot plant scale are presented. The possible applications are discussed.

1. INTRODUCTION

As an effect of contemporary technological processes a lot of harmful dust and gases are produced. Moreover, gas impurities and aerosols (dusts, mists) often require simultaneous removal from waste gases. In many cases, particularly when it is not in conflict with further utilization of wastes, both dusts and detrimental gases should be removed in the same apparatus.

It may be accomplished by some types of gas scrubbers only. For example: spray scrubbers, fluidized bed and foam scrubbers, self-induced spray scrubbers and Venturi scrubbers.

In some cases the method for simultaneous dry or quasi-dry filtration and sorption in chemically reactive bed may be effective.

Some types of scrubbers (spray scrubbers, fluidized bed and foam scrubbers, as well as classic Venturi scrubbers) are characterized by formation of dust deposits and overgrowth of crystals, particularly in nozzles and in sieve plates, therefore they are troublesome in operation. Moreover, the fluidized bed and foam scrubbers are susceptible to possible changes in hydrodynamic parameters of operation. Among the types specified only Venturi scrubbers enable coagulation (or coalescence) of colloidal suspensions.

* Institute of Environment Protection Engineering of the Technical University of Wrocław, pl. Grunwaldzki 9, 50-377 Wrocław, Poland.

Systems of circulation and atomization of working liquid determine simplicity of design and reliability of scrubbers. The systems in which circulation and atomization of liquid are accomplished without any pumps and nozzles seem to be particularly advantageous. The scrubbers with self-acting circulation of liquid, e.g. self-induced spray scrubbers and injection Venturi scrubbers, called further the injection scrubbers, are the examples of such a device. Figure 1 shows a schematic diagram of injection scrubber.

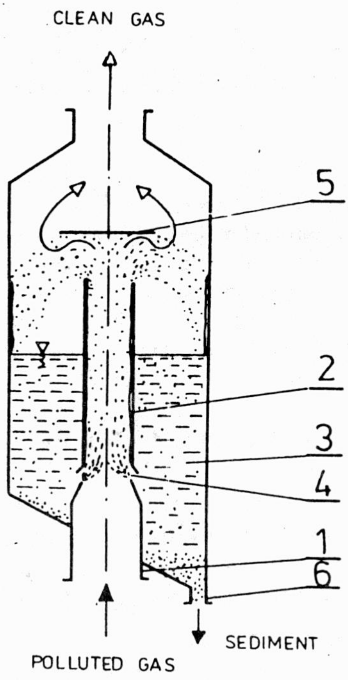

Fig. 1. Operating principle for injection scrubber
1 – gas inlet, *2* – throat, *3* – tank,
4 – liquid inlet, *5* – droplet separator, *6* – sediment outlet

Operating liquid is introduced into the gas stream at a small hydrostatic pressure, or there occurs an entrainment of liquid drops due to friction of gas. Because of heavy aerodynamic operation of gas, the stream of working liquid is distorted, forming stream filaments and films, then (in vicinity of the injection cross-section) it breaks up into small droplets conveyed from the liquid to gas. Some drops form a liquid film on walls of the throat. Good contact of liquid and gas in the throat of the scrubber provides effective dedusting, absorption of gas impurities, moistening and cooling of waste gases. Purified and cooled gases are separated from working liquid which due to the force of gravity flows down the scrubber to be recirculated.

Table 1

Some features of injection scrubbers suitable for simultaneous particle collection and absorption of gas impurities

Type of scrubber	Removal ability of respirable aerosol particles	Removal ability of colloidal aerosol particles	Self-acting circulation of liquid	Compact
Spray scrubber	–	–	–	–
Fluidized bed scrubber	+	–	–	–
Foam scrubber	+	–	–	–
Self-induced spray scrubber	+	–	+	+
Impacting scrubber	+	–	+	+
Venturi scrubber	+	+	–	–
Venturi injection scrubber	+	+	+	+

Injection scrubbers are characterized by their compact design. The most characteristic design data are as follows: 0.8–3.2 m^3 of space volume required and 300–1800 kg of apparatus per 1 kg/s of dirty gas stream (for comparison, for filtres or electrostatic dust collectors of similiar effectiveness these values amount to 9–34 m^3/kg/s, 640–4300 kg/kg/s and 28–38 m^3/kg/s, 1940–2600 kg/kg/s, respectively). It becomes extremely significant as the need arises for designing a gas purification system in existing, particularly old plants.

Table 1 enables comparison of some features of the gas washers which provide simultaneous dedusting and absorption of gas impurities. It may be noted that injection scrubbers are extremely favourable. Some of more often used types shows figure 2.

Their design and operation principles provide a relatively wide range of application. Injection scrubbers are particularly effective in the case of need for:

1. Dedusting (removal of colloidal, toxic dust particles of condensation origin) of humid gases and removal of readily soluble gas impurities.

2. Effective dedusting of waste gases of variable temperature.

3. Effective absorption accompanied by chemical reaction between dust and gas absorbed.

4. Demisting (including the hydrophobic droplets).

Moreover, injection scrubbers may be used for cooling down and primary moistening of waste gases or for oxygenating water, sewages, leaching liquids, etc.

Bearing in mind an almost universal application of the scrubbers, the scientists from the Institute of Environment Protection Engineering since 1972 have been working on improvement of design and operation features of the injection scrubbers.

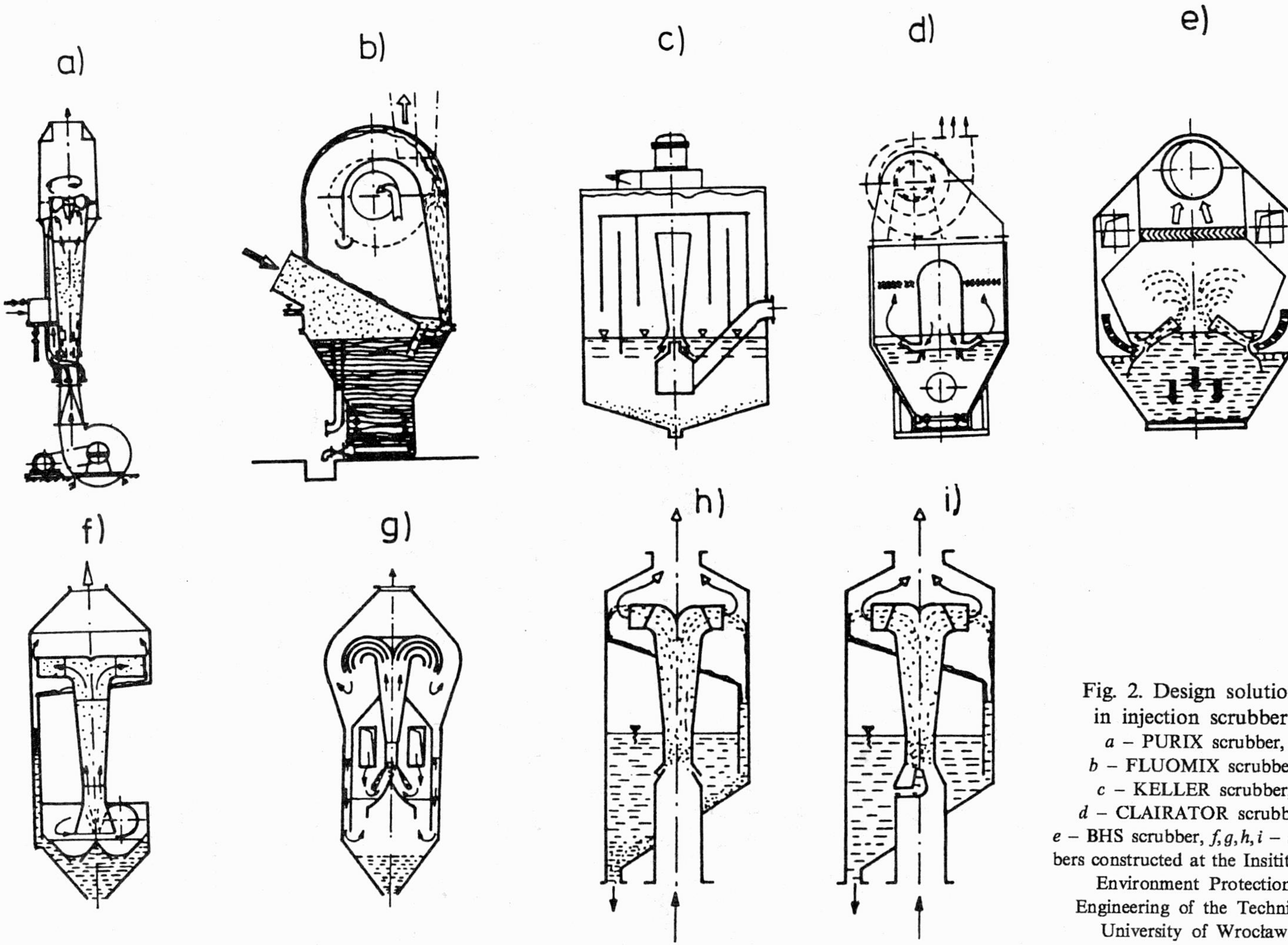

Fig. 2. Design solutions in injection scrubbers
a – PURIX scrubber,
b – FLUOMIX scrubber,
c – KELLER scrubber,
d – CLAIRATOR scrubber,
e – BHS scrubber, *f*, *g*, *h*, *i* – scrubbers constructed at the Insititute of Environment Protection Engineering of the Technical University of Wrocław

2. GENERAL ESTIMATION OF THE STATE OF KNOWLEDGE

The prerequisite for correct design and operation of injection scrubbers is thorough knowledge of the liquid and gas flow mechanisms. Parameters of the two-phase flows, which occur in the scrubbers, are limited to a quite distinct area. Generally, velocities of gas range from 20 to 50 m/s, and liquid to gas ratios range between 10^{-3} and 5×10^{-3} m^3/m^3.

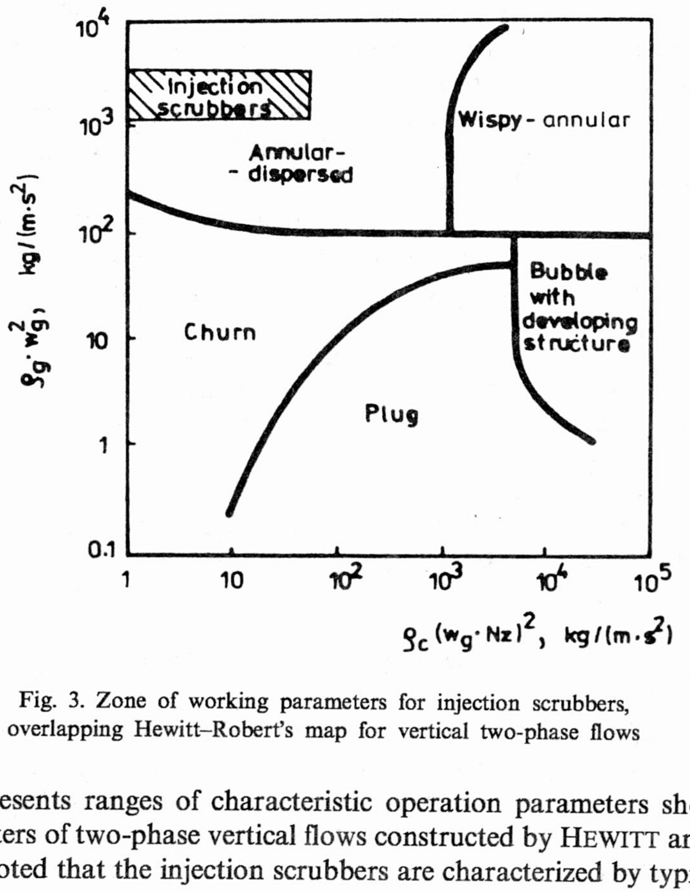

Fig. 3. Zone of working parameters for injection scrubbers, overlapping Hewitt–Robert's map for vertical two-phase flows

Figure 3 presents ranges of characteristic operation parameters shown on the map of parameters of two-phase vertical flows constructed by HEWITT and ROBERTS [1]. It can be noted that the injection scrubbers are characterized by typical annular dispersed flows.

In most of the papers that have hitherto been published, the processes occurring in injection scrubbers are described basing on some considerable simplifications, e.g. assuming droplet flows in the Venturi tube instead of the annular dispersed flows encountered in reality. It is somewhat strange because the annular dispersed flows have intensively been studied for over thirty years (however, in other fields of technique) [1]–[8]. Particularly in the last two decades, the theory of mechanics and heat transfer during such flows was intensively developed in order to improve cooling down of nuclear reactors. Perhaps due to such practical applications attention of investigators was attracted to the fully developed annular dispersed flows, occurring under steady conditions of long pipelines of the reactor cooling systems. Therefore, the experiments do not explain processes occurring in the injection scrubbers. Not fully developed flows, characteristic of injection scrubbers, are characterized by migration of liquid between gas core and liquid film on walls as well as by changing axial velocity of droplets and changing concentration of liquid in gas phase. Distance from the cross-section of injection to the cross-section of the fully developed flow is evaluated as equal to 20–100 diameters of the apparatus [1], [9]–[15]. Almost all experiments were conduced at greater distances. However, taking account of injection scrubbers, the most attractive are processes occurring in the distances much below 20 diameters. Both our investigations [9], [16], [17] and other papers [18]–[20] clearly prove that basic processes of gas cleaning (dedusting, absorption) occur in a relatively short zone, just behind the injection cross-section. It is called by MATROZOV and FILATOV [20] *a liquid dispersion zone*, which may suggest that the dispersion process is responsible for such favourable results of purification of gas. However, they did not attempt to base their hypotesis on a physical background.

Matrozov and Filatov, as well as other investigators [18], [21]–[27], showed that in the dispersion zone there are located big interfacial areas. It has been proven by chemical methods only (without any attempts to explain the mechanism of flow and geometry of interfacial surface).

Therefore, processes occurring inside the injection scrubbers are still insufficiently known. It refers both to the theory of not fully developed annular dispersed flows and accompanying momentum, heat and mass transfer processes.

3. EXAMPLES OF APPLICATION OF INJECTION TYPE WASHERS

Production of lead glass is very noxious for environment due to emission of toxic, fine and non-wettable particles of dust (figure 4) comprising lead, antimony and arsenic oxides, as well as due to emission of nitrogen and sulfur oxides.

Waste gases from tank furnaces must be effectively dedusted and cleaned from toxic gases to meet requirements of air protection regulations. In case when gas scrubbing may be carried out, the alkaline components of the dusts can be used as suitable reagents (by circulation of suspension in a scrubber) in the process of chemical absorption. The process may be successfully carried out in the injection scrubbers without other reactants.

In the Glass-Work IRENA in Inowrocław there were designed two separate waste gas cleaning systems to cover needs of two lead glass tank furnaces. Both systems, each of the capacity of approx. 11,000 m^3/h, were based on injection scrubbers designed in the Institute of Environment Protection Engineering in Wrocław [29].

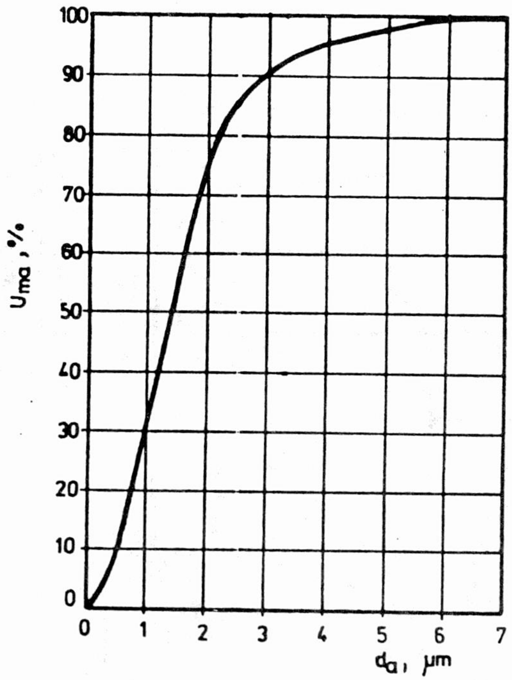

Fig. 4. Size distribution of dust conveyed from lead glass melting tank furnace

Design of the scrubbers has been patented [31]. Figure 5 shows the flow sheet of the gas cleaning systems [30]. Combustion gases are taken from a ceramic channel behind heat regeneration chambers of the tank furnaces, then introduced into a heat exchanger to be cooled down from 300–350°C to 110–120°C. Heat recovered from gases is utilized for heating of water used during decoration of glass products. The outlet temperature of gases must be kept within the above-mentioned range to avoid both condensation and evaporation of water and to maintain constant volume of liquid circulating in the system.

After cooling gases are introduced into the injection scrubber for cleaning and further cooling down to 45–50°C, then blown out through a stack. Part of deposit cumulating at the bottom of the scrubber is periodically removed and in the form of dense sludge dewatered in a drying tank installed on a flue gas channel. Dry deposit, comprising approx. 90% of PbO, is collected in containers and sold to leadworks.

The gas cleaning system (patented [32]) is a waste-free technology with the following operation parameters:

1. Efficiency of dedusting amounts to 94–96% within the range of dust concentration of 100–700 mg/m^3.

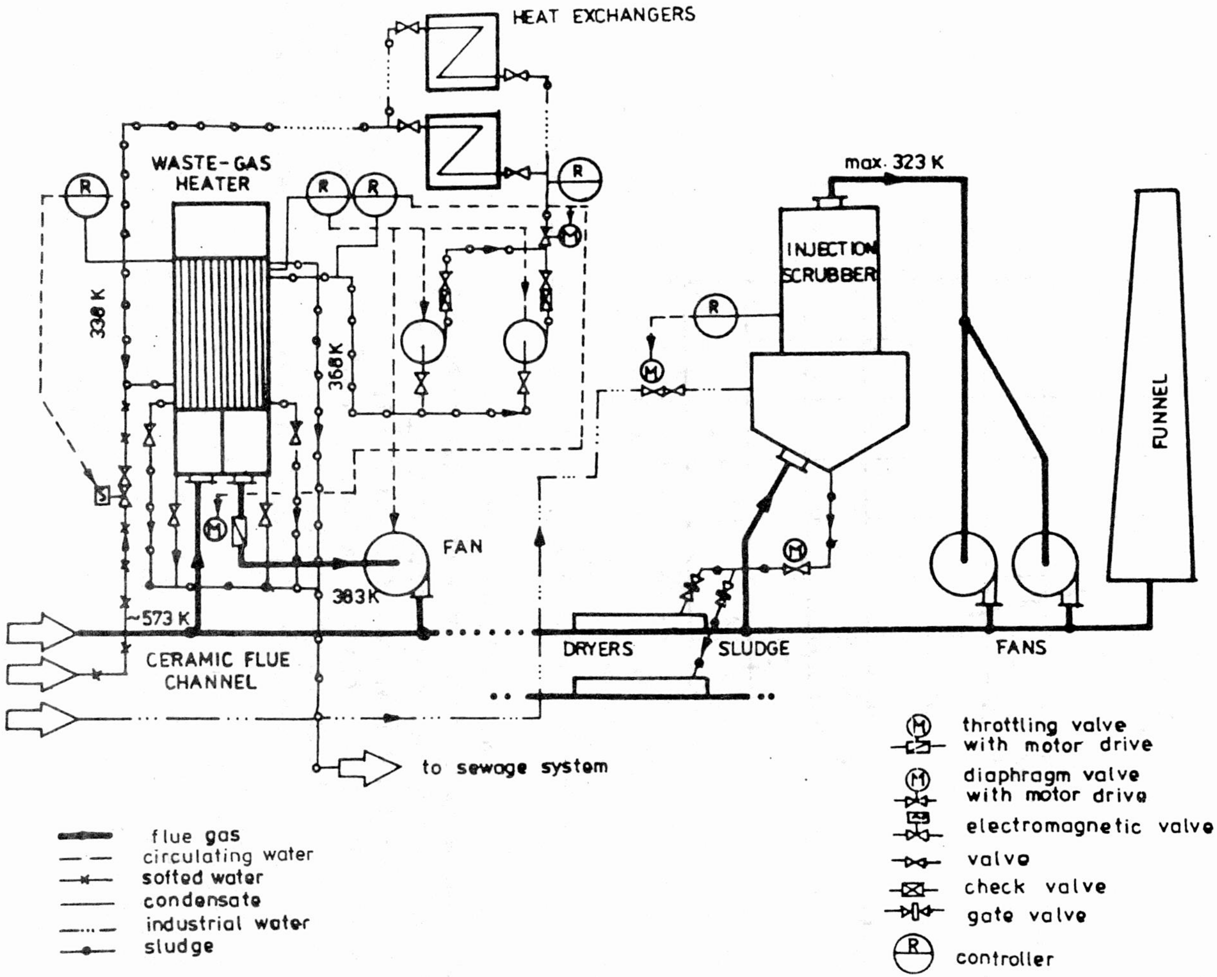

Fig. 5. Diagram of the system for cleaning of flue gases emitted from lead glass melting tank furnaces at HSG "IRENA" in Inowrocław

2. Maximum peak concentration of dust in cleaned off gases introduced to atmosphere does not exceed 30 mg/m^3.

3. Average dust concentration in clean outlet gases amounts to 13–14 mg/m^3.

4. Efficiency of absorption, stimulated by alkaline components of the dust only, amounts to 21–23% for NO_x and 39–45% for SO_2.

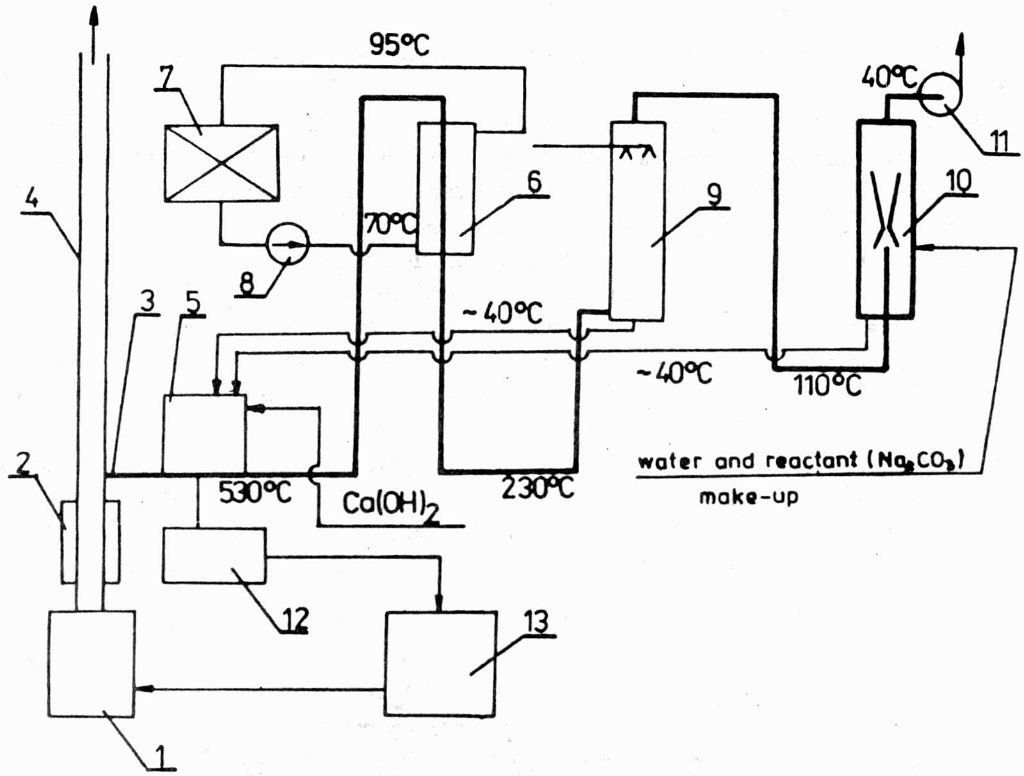

Fig. 6. Diagram of the system for cleaning of flue gases emitted from borosilicate glass melting tank furnaces when producing glass fibre
1 – tank furnace, *2* – recuperator, *3* – pipeline, *4* – funnel, *5* – dryer, *6* – technological heat exchanger, *7* – heater of water, *8* – circulating pump, *9* – spray scrubber, *10* – injection scrubber, *11* – fan, *12* – granulator, *13* – batch manufacture

An another example is the gas cleaning system for dedusting and removal of fluorine compounds from gases produced in borosilicate glass melting furnaces during a glass fibre production processes [43], also designed in our Institute. Injection scrubber [31] was used as dust collector and absorber. Both the system and the scrubber were tested [33] in a pilot scale in the Glass Fibre Department of the Krosno Glass Works. Some characteristic parameters of waste gases from the borosilicate glass melting furnaces are specified below [33]:

1. Temperature of gas behind recuperator ranges from 480 to 530°C.
2. Average concentration of dust is approx. 100 mg/m^3.
3. Share of grains
below 2μ – 56% w/w,
below 4μ – 73% w/w,
below 6μ – 88% w/w,
below 10μ – 98% w/w.
4. Average concentration of fluorine compounds (calculated as HF) is approx. 150 mg/m^3.

Figure 6 shows the flow sheet of the system. It is a waste-free technology. Simple design of the scrubber provides reliable operation despite the suspension of dust in recirculating liqiud, precipitation of silica and considerable corrosive power of media.

The pilot plant tests gave the following results [33]:

1. Total efficiency of dedusting ranging from 95 to 97%.
2. Efficiency of flourine compounds removal in the range of 97–98%.

Next example may be the demisting system developed in the Institute for Machine-Building Industry. In the course of metal working, commonly oil and water–oil cutting fluids are used. The fluids intensively evaporate in contact with hot surface of tool for metal working. Next, vapours condense in cool air of room forming finely dispersed oil mist. It may be dangerous for operators (cancers of the respiratory system and skin, injuries due to slippery floor and platforms, etc.), particularly when many machines operate in badly ventilated house. Oil mist is also noxious for the environment when removed with exhaust ventilation air to atmosphere.

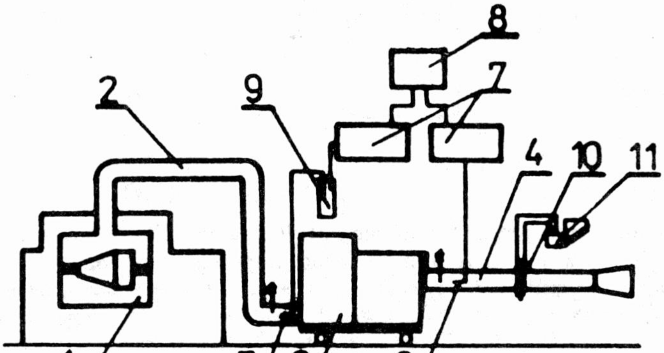

Fig. 7. Diagram of a prototype system for oil–mist separation, including measurement fittings
1 – spinner, *2* – pipeline, *3* – injection separator, *4* – pipeline, *5, 6* – probes, *7* – nephelometric gauges, *8* – recorder, *9* – heavy-dispersion mist separator, *10* – flowmeter, *11* – micromanometer

Design of an injection scrubber, which may be used for removal of oil mist, is the result of many years of investigations carried out in our Institute [17], [34]–[40]. It is protected by a patent [31] and registered as an utility model [41]. The apparatus was installed in the Agricultural Machines Factory AGROMET-ARCHIMEDES in Wrocław.

Figure 7 shows in diagrammatic form a prototype of the demister, installed together with a numerically controlled spinning lathe, and arrangement of control instruments. The machine oils no. 10 and no. 20 were used as cutting fluids.

Total efficiency of mist removal (fine, condensation type mist with droplets up to 1 μm and coarse mist mechanically dispersed) exceeded 99.7%. The average operational efficiency of removal of the fine mist amounted from 65 to 87%, depending on original concentration in air. Average concentrations of oil mist in demisted air ranged from 3 to 14 mg/m^3.

Introduction of strict domestic regulations referring to protection of atmospheric air against pollution [42], particularly limitation of permissible emission of impurities from combustion of fuels for energetic needs, causes that the owners of many small and average boilerhouses face the necessity of better cleaning of flue gases. Up to date, such boilerhouses operated without any air protection equipment or used only cyclone separators, often ineffectively operating.

Specific feature of the boilerhouses is lack of skilled personnel (except larger industrial units operated by skilled staff) which may operate considerably complex dedusting and desulphuring systems. Therefore, in order to meet the existing and future requirements of regulations (aimed at reduction of impurities in air) the following devices are needed:

1. Simple apparatus for purification of flue gases, enabling simultaneous dedusting and desulphurization of gases.

2. Apparatus reliable and easy in maintenance and operation.

3. Dust collectors-absorbers using circulating suspension of precipitated dust and concentrated reactants (e.g., lime) to reduce costs of cleaning.

The injection scrubbers may readily meet all the requirements specified.

Experiments carried out in pilot plant scale proved that the injection scrubber is suitable for simultaneous dedusting and sulfur removal from flue gases. An injection scrubber of capacity 470 m^3/h and pressure drop of 5.5–5.6 kPa installed by the WCO-80 type boiler fired with fine coal gave 99% efficiency of dedusting. Efficiency of sulfur dioxide removal, depending on kind of reactant used, amounted to

90% for hydrated lime,

68% for magnesium lime,

91% for ground brown coal slag from the Konin mine,

67% for raw brown coal slag from the Konin mine,

31% for ground hard coal from the Jaworzno mine.

The result are very prospective and prove that the injection scrubbers are suitable for cleaning of flue gases because of their effectiveness, easiness in operation and reliability even when high concentrations of waste reactants are used.

Bearing in mind the papers cited and the results of own investigation, the potentially profitable applications of the injection scrubbers have been compiled in table 2.

Table 2

Possible applications of the injection scrubbers

Processes	Dedusting	Absorption	Demisting
1	2	3	4
		Metallurgy	
Cleaning of gases from coke quenching (particularly with coke wastewater)	Removal of coal dust	Removal of SO_2, phenol, NH_3 and H_2S	–
Cleaning of sinter plant gases	Removal of macroscopic and colloidal dust	Removal of SO_2 and NO_2	–
Cleaning of cupola gases	Removal of dust particles, mainly macroscopic	Removal of SO_2 and NO_2	–
Cleaning of shaft furnace gases in copper works	Removal of macroscopic and colloidal particles comprising heavy metals (Cu, Pb, Zn)	Removal of SO_2 and NO_2	–
Cleaning of shaft furnace gases in lead works	Removal of macroscopic and colloidal particles comprising lead	Removal of SO_2 and NO_2	–
Cleaning of gases from aluminium works	Removal of macroscopic and colloidal particles	Removal of HF	–
		Mining	
Cleaning of gases from coal concentrate dryer	Removal of coal dust	Removal of SO_2 and NO_2	–
Cleaning of gases from copper concentrate dryer	Removal of dust comprising considerable amounts of heavy metals (Cu, Pb, Zn)	Removal of SO_2 and NO_2	–
		Chemistry	
Cleaning of gases from absorption towers in sulfuric acid plants	–	Removal of SO_2	Removal of mist of sulfuric acid

1	2	3	4
Secondary cleaning of fluorine bearing gases in superphosphate plants	–	Removal of HF and SiF_4	–
	Engineering		
Cleaning of air during machining operations (turning, cutting, grinding, spinning, rolling)	Removal of colloidal dust particles	–	Removal of macroscopic and colloidal oil mist
Cleaning of air from heat treatment operations (hardening)	–	–	Removal of colloidal oil mist
	Glass-making		
Cleaning of gases from lead glass melting furnaces	Removal of macroscopic and colloidal particles comprising considerable amounts of Pb, As, Sb	Removal of NO_2 and SO_2	–
Cleaning of gases from borosilicate glass melting furnaces	Removal of macroscopic and colloidal dust particles having considerable amounts of B and Pb	Removal of HF, SiF_4, NO_2 and SO_2	–
Cleaning of gases from glass melting furnaces – turbid glass type	Removal of macroscopic and colloidal dust particles	Removal of HF, SiF_4, NO_2 and SO_2	–
Cleaning of gases from tank furnaces in production of commercial glass fibres	Removal of macroscopic and colloidal dust particles comprising considerable amounts of boron	Removal of HF, SiF_4, NO_2 and SO_2	–
Cleaning of gases from glass melting furnaces for insulating fibrous products	Removal of macroscopic and colloidal dust particles comprising considerable amounts of lead	Removal of NO_2 and SO_2	–
Purification of ventilation air from chemical polishing operations	–	Removal of HF and SO_4	Removal of colloidal mist of HF and H_2SO_4

1	2	3	4
	Heat production		
Cleaning of flue gases from hard coal and brown coal fired boilers with mechanical stokers	Removal of dust particles (mainly macroscopic)	Removal of SO_2 and NO_2	

REFERENCES

[1] BUTTERWORTH D., HEWITT G.F., *Two-Phase Flow and Heat Transfer*, United Kingdom Atomic Energy Authority Research Group, Oxford University Press, 1977.

[2] MAYINGER F., *Strömung und Wärmeübergang in Gas-Flüssigkeits Gemischen*, Springer, Wien 1982.

[3] BRAUER H., *Grundlagen der Einphasen und Mehrphasenströmungen*, Verlag Sauerländer, Frankfurt am Main 1971.

[4] AZBEL D., *Two-Phase Flows in Chemical Engineering*, Cambridge University Press, 1981.

[5] NIGMATULIN R.J., *Osnovy mekhaniki geterogennykh sred*, Nauka, Moskva 1978.

[6] DOBRAN F., *Theory of Multiphase Mixtures*, Int. J. Multiphase Flow, 11, 1 (1985), pp. 1–30.

[7] JAMES P.W., WILKES N.S., CONKIE W., BURNS A., *Developments in the Modelling of Horizontal Annular Two-Phase Flow*, Int. J. Multiphase Flow, 13, 2 (1987), pp. 173–198.

[8] WALLIS G.B., *One-Dimensional Two-Phase Flow*, McGraw-Hill, 1969.

[9] MELOCH H., CYBULSKA H., KNOP F., RYDOSZ K., *Badania parametrów ruchu filmu cieczy w iniekcyjnym kontaktorze w zakresie wysokich prędkości przepływu fazy gazowej (0,1 do 0,3 Ma)*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 67/87.

[10] TAKAHAMA H., OKADA O., FUJITA H., MIZUNO A., *Study on Annular Mist Flow in Pipe*, Bull. JSME, 26, 222 (1983), pp. 2091–2099.

[11] GILL L.E., HEWITT G.F., *Sampling Probe Studies of the Gas Core in Annular Two-Phase Flow*, Chem. Eng. Sci., 23 (1968), pp. 677–686.

[12] TAITEL Y., BORNEA D., DUKLER A.E., *Modelling Flow Pattern Transitions for Steady Upward Gas–Liquid Flow in Vertical Tubes*, AIChE J., 26, 3 (1980), pp. 345–354.

[13] MATSUI G., *Identification of Flow Regimes in Vertical Gas–Liquid Two-Phase Flow Using Differential Pressure Fluctuations*, Int. J. Multiphase Flow, 10, 6 (1984), pp. 711–720.

[14] WEISMAN J., DUNCAN D., GIBSON J., CRAWFORD T., *Effects of Fluid Properties and Pipe Diameter on Two-Phase Flow Patterns in Horizontal Lines*, Int. J. Multiphase Flow, 5 (1979), pp. 437–462.

[15] JEPSEN J.C., *Mass Transfer in Two-Phase Flow in Horizontal Pipelines*, AIChE J., 16, 5 (1970), pp. 705–711.

[16] MELOCH H., *Opracowanie podstaw konstrukcji płuczki z samoczynnym obiegiem cieczy przeznaczonej do odpylania i sorpcji gazów kwaśnych, zwłaszcza szklarskich*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 39/80.

[17] MELOCH H., KABSCH P., KACZMARSKI K., *Opracowanie sposobu oraz podstaw konstrukcji urządzeń do separacji mgły olejowej emitowanej w procesach obróbki mechanicznej z zastosowaniem w procesie oczyszczania kontaktorów iniekcyjnych*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 21/83.

[18] MAYINGER F., NEUMANN M., *Neue Gleichung zur Berechnung der Staubabscheidung im Hochleistungs-Venturiwäscher*, VDI-Berichte, 349 (1979), pp. 309–320.

[19] HESKETH H.E., MOHAN K., *Specifying Venturi Scrubber Throat Length for Effective Particle Capture at Minimum Pressure Loss Penalty*, JAPCA, 33, 9 (1983), pp. 854–857.

[20] Matrozov V.J., Filatov N.N., *Massobmen v absorbere Venturi v zone dispergirovaniya zhidkostnogo potoka*, Zhurnal Prikladnoi Khimii, 1 (1975), pp. 103–108.

[21] Munter R.R., Loorits Ch.A., Sijrde E.K., *Sravnitelnaya ocenka razlichnykh massoobmennykh apparatov po velichine aktivnoi poverkhnosti kontakta*, Zhurnal Prikladnoi Khimii, 10 (1979), pp. 2336–2338.

[22] Shilimkan R.V., Stepanek J.B., *Interfacial Area in Cocurrent Gas–Liquid Upward Flow in Tubes of Various Size*, Chem. Eng. Sci., 32 (1977), pp. 149–154.

[23] Radhakrishnan V.R., Mitra A.K., *Pressure Drop, Holdup and Interfacial Area in Vertical Two-Phase Flow of Multi-Jet Ejector Induced Dispersions*, Can. J. Chem. Eng., 62, 2 (1984), pp. 170–178.

[24] Nagel O., Kürten H., Sinn R., *Stoffaustauschfläche und Energiedissipationsdichte als Auswahlkriterien für Gas/Flüssigkeits-Reaktoren*, Chemie-Ing. Techn., 44, 14 (1972), pp. 899–903.

[25] Nagel O., Kürten H., Sinn R., *Strahldüsenreaktoren*, Chemie-Ing. Techn., 42, 7 (1970), pp. 474–479.

[26] Kasturi G., Stepanek J.B., *Interfacial Area in Cocurrent Gas–Liquid Flow*, Chem. Eng. Sci., 29 (1974), pp. 713–719.

[27] Wales Ch. E., *Physical and Chemical Absorption in Two-Phase Annular and Dispersed Horizontal Flow*, AIChE Journal, 12, 6 (1966), pp. 1167–1176.

[28] Bilicki Z., *Analiza energetyczna struktur przepływu dwufazowego w adiabatycznych kanałach pionowych*, Redakcja Wydawnictw Ciągłych Instytutu Maszyn Przepływowych PAN, Gdańsk 1978.

[29] Kabsch P., Meloch H., Marciniak A., *Wdrożenie technologii oczyszczania i odzysku ciepła z gazów odlotowych z wanien gazowych do wytopu szkła kryształowego*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 10/84.

[30] Kabsch P., Meloch H., Kaczmarski K., *Technologia oczyszczania gazów powstających przy wytopie szkła kryształowego wraz z odzyskiem i wykorzystaniem ciepła odpadowego*, Szkło i Ceramika, XXXX, 7–9 (1989), pp. 3–6.

[31] Pat. nr 220226 PRL.

[32] Pat. nr 209325 PRL.

[33] Gawor J., *Badania nad technologią oczyszczania gazów powstających przy produkcji włókna szklanego*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 2/84.

[34] Meloch H., Kabsch P., *Opracowanie sposobu oraz podstaw konstrukcji urządzeń do separacji mgły olejowej emitowanej w procesach obróbki mechanicznej z zastosowaniem w procesie oczyszczania kontaktorów iniekcyjnych*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 12/82.

[35] Meloch H., *Opracowanie sposobu oraz podstaw konstrukcji urządzeń do separacji mgły olejowej emitowanej w procesach obróbki mechanicznej z zastosowaniem w procesie oczyszczania kontaktorów iniekcyjnych*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 37/85.

[36] Kabsch P., Meloch H., Kaczmarski K., *Mokra metoda separacji mgły olejowej*, Ochrona Powietrza, 2 (1987), pp. 32–37.

[37] Kabsch P., Kaczmarski K., Meloch H., *Investigations of Oil Mist Separation in Injection Contactor*, Envir. Prot. Eng., 10, 3 (1984), pp. 47–56.

[38] Jeżowiecka-Kabsch K., Meloch H., Zalewski H., *Coalescence of Oil Mist Droplets in Non-Stationary Air Flux*, Envir. Prot. Eng., 10, 1 (1984), pp. 21–30.

[39] Kabsch P., Kaczmarski K., Meloch H., *Separation of Oil–Mist Droplets in an Injection Contactor*, Envir. Prot. Eng., 13, 1 (1987), pp. 73–81.

[40] Kabsch P., Meloch H., Kaczmarski K., *New Wet Separator of Airborne Oil–Mist Droplets*, Envir. Prot. Eng., 13, 2 (1987), pp. 75–82.

[41] Wzór użytkowy nr 72780 PRL.

[42] Monitor Polski nr 15, 14 marca 1990 r., Rozporządzenie Ministra Ochrony Środowiska, Zasobów Naturalnych i Leśnictwa z dnia 12 lutego 1990 r. w sprawie ochrony powietrza przed zanieczyszczeniem.

[43] KABSCH P., MELOCH H., *Technologia i urządzenia do oczyszczania gazów odlotowych powstających przy produkcji włókna szklanego w ZWZ Krosno*, Raporty Instytutu Inżynierii Ochrony Środowiska Politechniki Wrocławskiej, seria SPR, nr 39/81.
[44] YCY D.A., BOMADY F.M., *Guide to Wet Scrubbers*, Chem. Prosess., 11 (1983), pp. 47–57.

APPENDIX

ULRICH [7], [11] reports that the injection type gas washers may be readily used for absorption of HCl, HBr, nitrose, CS_2 and Cl_2.

YCY and BOMADY [44] in their *Guide to Wet Scrubbers*, published in Chemical Processing (1983), mentioned more than 50 successful applications of the Venturi washers for dedusting, desulfurization, NO_x removal and other absorption processes, including removal of organic solvents and deodorization. Moreover, they describe applications for demisting and removal of soluble particles of dust, as well as cooling and humidification of gases.

PŁUCZKI INIEKCYJNE – STAN WIEDZY I ZASTOSOWANIA

Przedstawiono tendencje dominujące w oczyszczaniu gazów odlotowych. Przejawiają się one m.in. w dążeniu do upraszczania budowy i zwiększania niezawodności działania urządzeń. Na tym tle wykazano zalety płuczek iniekcyjnych. Oceniono zasób wiedzy o procesach przebiegających w płuczkach iniekcyjnych i trudności napotykane w ich projektowaniu. Zaprezentowano przykłady zastosowań iniekcyjnych płuczek, zrealizowanych przez autorów w skali przemysłowej lub pilotowej, oraz przedstawiono listę możliwych zastosowań tych płuczek.

ИНЪЕКЦИОННЫЕ СКРУБЕРЫ – СОСТОЯНИЕ ЗНАНИЙ И ПРИМЕНЕНИЯ

Представлены направления, преобладающие в очистке отходящих газов. Они заключаются м.др. в стремлении к упрощению конструкции и к увеличению надежности работы устройств. На этой основе представлены положительные черты инъекционных скрубберов. Оценены знания на тему процессов, протекающих в инъекционных скрубберах и трудности, встречаемые в их проектировании. Представлены примеры применений инъекционных скрубберов, выполненных авторами в промышленном или пилотажном масштабе, а также представлен список возможных применений этих скрубберов.