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(54) **SYSTEM FOR OPTIMIZING COMBUSTION PROCESSES BY MEANS OF DIRECT MEASURES
INSIDE THE HEARTH**

(57) System consisting of a probe or probes (1) and in a variety of openings (2) that allow the accomplishment of direct measurements or characterisations (gas extraction or placing of sensors) in the interior of the furnace (3) of industrial boilers. These local measurements intend to optimise the operation of each burner, allowing the global improvement of the boiler operation.

The probes (1) are designed with very narrow transversal sizes, to allow them to pass through the openings (2) carried out on the membranes (4) (typically around 20 mm) which join the water tubes (5), making up the water walls of the boiler, making the mentioned local measurements feasible with no need to undertake substantial modifications in the boiler.

Additionally, the subject of this patent is the fully automated version of the described system, that allows the continuous characterisation and optimisation of boiler combustion conditions, as well as its application to any other combustion process.

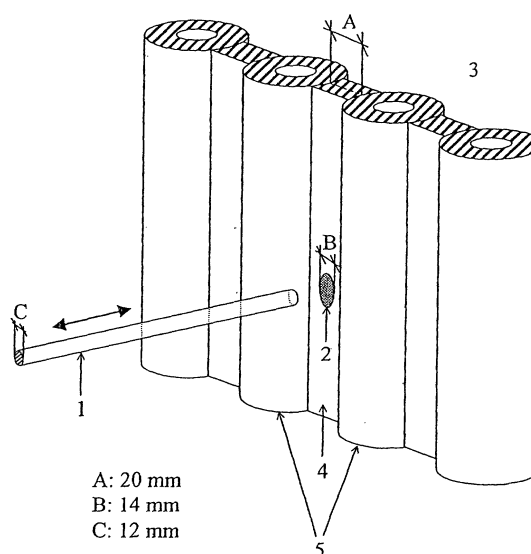


Fig. 1: System diagram (basic version)

Description

[0001] The system object of the patent consists, in its basic version, of a probe or probes and in a variety of openings, that by its special characteristics, allow the accomplishment of measurements or characterisations in high temperature areas (nearness of the burners, or any other area of the interior of the furnace of industrial boilers). These local measurements intend to optimise the operation of each burner, allowing the global improvement of parameters like combustion efficiency, loss on ignition, polluting agents formation and slagging processes.

[0002] The small holes are drilled through the membranes which join the water tubes making up the water walls of these type of facilities, making feasible the mentioned local measurements with no need to undertake substantial modifications in the boiler. The probe is designed taking into account the limitation entailed by the membranes width (typically around 20 mm) and, therefore, the openings carried out on them.

[0003] Additionally, the subject of this patent is the fully automated version of the described system, that allows the continuous characterisation and monitoring of boiler combustion conditions.

[0004] These systems are equally applicable to optimisation of industrial furnaces, through the adjustment of their burners by means of measuring in areas of high temperatures.

BACKGROUND OF THE INVENTION

* Sector of the Technique

[0005] Industrial furnaces are facilities where the fuel (pulverised coal, fueloil, gasoil, gas, etc) is injected into the combustion chamber through burners tips, where it reaches the ignition point and burns to produce heat. This heat is transmitted to the water that circulates through the pipes that make up the boiler walls, and to other heat exchanging equipment, producing steam at high pressure and temperature. The energy of this steam may have a use in several industrial operations or it may be recovered as mechanical energy in a turbine, with the possibility to be subsequently transformed into electric energy by means of an alternator connected to the turbine.

[0006] The performance and generation of pollutants in industrial boilers depends largely on the correct distribution of fuel and air in the furnace, and so the existence of critical areas with an inappropriate air/fuel ratio will negatively affect these extremely important parameters. In the same way, in the specific case of coal, these imbalances may generate substoichiometric areas in which the fusion point of the ash is reduced, facilitating its accumulation on the boiler tubes (slagging). This phenomenon gives rise to important heat transfer losses, and can cause problems which make it necessary

to shut down the facility, with the consequent loss of production.

[0007] These imbalances between the proportions of air and fuel are also very problematic for the burners used in the furnaces of any type of industrial process, affecting their energetic performance, as well as the quality of the products and byproducts obtained from them.

* State of the Art:

[0008] In industrial furnaces, mainly at thermal power stations, the use of systems for the analysis of combustion gases located at the boiler outlet is frequent. These systems are used for adjusting and controlling the overall combustion process. Thus, the determination of parameters such as the oxygen and carbon monoxide at the boiler outlet, allows the identification of the correct development of the combustion.

[0009] However, the optimisation of the process using these values has certain limitations, even when the analysis of gases is carried out at a large number of points uniformly distributed among the boiler outlets. These limitations, with respect to the distance from the actual combustion area, the evolution of the flame, and the degree of mixing of the gases in the measurement area, do not allow effective characterisation of each individual burner performance, and therefore do not permit optimisation of the overall combustion process.

[0010] In the current state of the art, different available equipments are commercialised by numerous companies (Storm Technologies, ESA, IFRF, etc), which allow direct determinations inside the furnace (water-cooled probes, suction pyrometers, high speed thermocouples, etc). However, these pieces of equipment are designed to measure through the boiler inspection ports, which are several centimetres in size and located only at certain points on the furnace.

[0011] Therefore, this type of measurement inside the furnace is not representative enough, since it is restricted to the areas where direct access is available through the inspection ports originally installed. This restriction exists because it would require important structural modifications to the design of the boiler tube layout to make more openings of this type (over 20 mm in size, and normally around 100 mm).

[0012] Other approaches attempt the characterisation of combustion processes consisting of systems based on sensors located on the boiler walls. These sensors measure the signals of different wavelengths produced by the combustion process itself. They can be divided into Passive Systems, which determine some property of the flames generated (such as flame detectors, infrared pyrometers, cameras or heat flow sensors located in the tubes); and Active Systems, which characterise the signals generated by emitters located in other areas of the boiler, that are attenuated or modified during their transmission through the furnace (for exam-

ple, systems based on acoustic principles).

[0013] Examples of these industrial applications based on sensors or "wall" or "contour" measurement systems are collected in numerous patents, as for example, US 4555800, US 3824391, US 4176369, DE 3224500, US 5794549, EP 0802372, DE 4328629 and US 4756684 (passive systems) and WO 9710473 (active systems), that are in any case indirect measurements of the real combustion process, since they are based on determinations taken at the edge of the furnace.

[0014] These facts justify the little information available about the real development of the combustion processes as far as their representativeness in the boilers of industrial size is concerned.

[0015] These limitations in the knowledge of the local combustion conditions are equally extrapolable to the furnaces of any type of industrial process.

DESCRIPTION OF THE INVENTION

[0016] This invention involves a system which allows measurements to be taken in any area of the interior of the furnace of industrial boilers, specially near the burners. Some examples of this type of measurement are the evaluation of local levels of gas concentrations, temperatures, heat flows, and even image capture, in these areas of high temperature and very limited access in boilers of traditional design. The aim of these measurements is to identify the combustion conditions at any particular point inside the boilers, in order to be able to optimise heat rate, consumption of auxiliaries, and generation of pollutants and slagging.

[0017] This local information makes it possible to consider the unit as a collection of small virtual units, each made up of a single burner. The targeted adjustment of each of these smaller units results in overall optimisation of the boiler.

[0018] In order to meet these goals, the system allows these measurements to be made through small openings made in the membranes which join the tubes making up the water walls of the boiler. The width of these openings (around 14 mm) is limited by the width of the membranes themselves (around 20 mm), while the height is unlimited, due to the geometry of the membranes.

[0019] This new concept for measurement inside the furnace of industrial boilers, makes it possible to place the openings in any location required, without being limited to those inspection ports included in the original design of the boiler, and permits the direct measurement of combustion conditions inside the furnace. In this way, it is possible to take measurements at the level of each burner in the boiler, without any significant structural modifications to the unit. In order to access the inside of the furnace, for the extraction of samples or the insertion of sensors, a water-cooled probe either made of or covered by ceramic material, has been specially de-

signed for insertion through these openings, which additionally is able to withstand the high temperatures (1400 - 1700 °C) in these areas of the furnace.

[0020] An optional upgrade to the system allows automatic operation by means of the following: motorization of the probe (insertion - extraction, lateral movement); a system of continuous treatment and analysis of the gas samples collected or of the data provided by the sensors inserted into the furnace by the probe; a cleaning system using a compressed air counterflow which guarantees the autonomy of the system between measurements; advanced monitoring software which, in addition to controlling the operation of the entire automated system and the correct processing of the results obtained, provides operational recommendations to the operator of the plant. These recommendations are based on results and the experience in the optimisation of this process.

[0021] The invention described is applicable, to the optimisation of any type of burner, for example those in industrial furnaces.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] For a better understanding of every description contained in this report, some drawings are supplied only to serve as accomplishment examples of some system variants.

[0023] Thus, Figure 1 presents a schematic drawing of the system in its basic version, where the sampling probe (1) is introduced through the opening (2) inside the furnace boiler (3). This small opening (2) is made in the membrane (4) which join the tubes (5) making up the water walls of the boiler, close to a facility burner.

[0024] Figure 2 represents a probe longitudinal section (1) in its cooled and gas sampling variant; the outer socket (6) of entrance and exit of the coolant fluid and its circulation once inside the probe is shown. Also, the sample aspiration conduct can be observed (7). Figure 3 presents a front view and a cross section of the opening (2) made in the membrane (4) between the tubes (5), for the sampling probe variant (1) shown in Figure 2 (cooled and for gas sampling).

[0025] Figure 4 presents a schematic drawing of an automated system version, specifically its variant for gas sampling, in which the sampling probes displacement can only be of insertion-extraction (a sampling probe by orifice), or with additional lateral displacement (a sampling probe for several orifices). Figure 5 shows the schematic drawing of the required elements for this variant.

DESCRIPTION OF A FAVOURITE ACCOMPLISHMENT

[0026] The access openings (2) are distributed throughout the boiler close to each burner. The detail of one of these openings, for the variant of cooled and gas

sampling probes variant, appears in Figure 3, where its geometry can be appreciated (two semicircles of 7 mm radius joined by a square of 14 mm side).

[0027] The water cooled probe is specially designed to support the high existing temperatures in this zone (between 1400 and 1700°C) and to accede to the interior of the boiler through the described orifices.

[0028] In its cooled gas sampling variant (Figure 2), a tube of rectangular section can be used for its construction (14 x 12 mm sides and 1 mm thick) and two half tubes (7 mm radius and 1 mm thickness) welded as shown in the figure Section A-a. In this same section the three resulting cameras can be appreciated (8, 9, 10) through which the refrigeration fluid, for example, water, flows. Out of these, the chamber in the middle (9) is crossed by a 6 mm diameter tube through which the gas sample is extracted to be analysed. These elements are assembled at the probes end by means of two half cones and two triangular plates, according to what is observed in the detail of the probes end (Figure 2). In the opposite end an outer socket is arranged (6) allowing the exit and entrance of the refrigeration fluid and of the sample collection tube.

[0029] Summarising, the route described by the cooling fluid is as follows: it enters through the orifice (11) into the A chamber socket (12), flowing then into the two sampling probe outer chamber (8) and (10). After reaching the end of the sampling probe the fluid returns through the central chamber (9) until reaching the B socket chamber (13) where it leaves the sampling probe through the orifice (14).

[0030] A system automation schematic drawing is presented in Figure 4. In this figure, the sampling probe (11), being cooled or not, is coupled to a pneumatic cylinder (15), controlled by a multiway valve (16), to insert or retract the probe in or out of the furnace boiler (3).

[0031] In the version for gas sampling and analysis, shown in the mentioned Figure 4, the sample collected by the probe passes through a heated filter to eliminate ash in suspension, and then goes to a set of valves which either send the sample to the conditioning system, or send pressurised air towards the heated filter and the probe, giving rise to a countercurrent which cleans both of these items.

[0032] A typical sample conditioning system (19) is made up of a condenser, a cooler, a filter and a pump. This conditioning system may be housed in a cabinet (20) located on the cylinder-probe assembly support, which can also be used to house the valves, or in an adjacent location in order to service several probes.

[0033] The sample is taken from the conditioning system to an analysis system, which consists essentially of a gas analyser (21), together with other filters, a humidity detector and a valve to control the input of samples to the analyser.

[0034] A programmable logic controller (PLC) (22) is used to collect the analysis results, monitor the entire process and report on possible incidents. This informa-

tion is sent to a control room computer (23) with the necessary user interfaces, which also collects information from other PCLs or monitoring systems. This computer also has software designed to offer operational recommendations to the plant operator, based on the readings, and on a number of rules gathered from experience on the optimisation of the process.

[0035] This latter version has, in general, more advantages from the point of view of investment and maintenance costs, although the characterisation period is slightly increased. The photograph in Figure 9 shows this design, which is schematically presented in the plant view of the drawing in Figure 12.

[0036] For the automated version with lateral displacement (one probe for several openings), Figure 5, the gases sampling probe (1) or the insertion of any sensor type into the furnace, the pneumatic cylinder (15), the multiway valve (16) which controls the cylinder and other auxiliary equipment (for example, in the case of the gas sampling version, the heated filter (17), the set of control valves (18) and the sample conditioning system (19) located in the cabinet (29), which may also house the valves (16) and (18)) are all located on a motorised (25) carriage (24). This makes it possible to move the whole assembly for taking measurements in other parts of the boiler.

[0037] The carriage (24) has several proximity sensors (26), which stop the motors at positioners (27) marking the exact position of the sampling points. In order for the carriage (24) to halt exactly at the right spot, an automated speed control (28) reduces the speed of the motors to a minimum as it approaches the positioner (27), due to a location signal provided by an appropriate device (e.g. an encoder (29) located on the carriage (24)).

Claims

1. System which allows measurements (by means of gas extraction or by insertion of sensors) in any area of the interior of the furnace (high temperature areas) of industrial boilers (as the ones in power plants), enabling combustion process optimisation in these facilities based on the results obtained by the local measurements; this system being **characterised by** and comprising the following elements: A) openings to access the furnace whose reduced dimensions (width lower than the membranes which join the tubes making up the water walls of the boiler, typically <20 mm) allow their placement on the mentioned membranes, in such a way that enable direct measurements to be taken inside the boiler (not only around its surrounding area), such as gas concentration measurements by means of sampling on a prefixed point and subsequent analysis, temperature and heat flow measurements, image capture at any wavelength, without the need of car-

rying out structural modifications to the design of the boiler tube layout; B) small transversal dimension sampling probe or probes, specially designed for the gas sampling and sensors insertion and conditioning in high temperature areas, through the previously mentioned small openings.

2. System according to claim 1, where the sampling probe or probes are inserted inside the boilers furnace through the small openings made in the proximity of each one of the burners, in order to allow their individual optimisation.

3. System according to claims 1 or 2, where the sampling probe or probes are cooled by water, water with additives, oil, oil with additives, air or any other kind of coolant fluid.

4. System according to claims 1 or 2, where the sampling probe or probes are constructed or externally covered by any kind of ceramic material, able to properly withstand the high temperatures existing inside the boilers furnace, avoiding in such a way the use of coolant fluids.

5. System according to claims 1, 2, 3 or 4, where the sampling probe or probes are fully automated and controlled by specific software for all their various displacement capabilities, using a sampling probe provided with the insertion-extraction movement capability, for each small opening through which the measurement is intended.

6. System according to claims 1, 2, 3 or 4, where the sampling probe or probes are fully automated and controlled by specific software for all their various displacement capabilities, using one or more sampling probes, each one of them used for measuring through several small openings, by means of lateral displacements in addition to the insertion-extraction movements.

7. System according to claim 6, allowing the sampling probe or probes to face up the small openings to access the inside of the furnace boiler with a precision of ± 1 mm, for example by the use of a combined action of proximity sensors for the final positioning at the right point, and an encoder that allows a change of speed of the lateral displacement depending on the distance to the positioner (greater speed at the beginning of the movement, and slower speed as it approaches the positioner); or by any other positioning system and determination of the sampling probe location that involves the use of infrared, acoustic, electromagnetic or any other wavelengths techniques.

8. System according to claims 5, 6, or 7, **character-**

ised, in its furnace gases analysis version, by locating the treatment and conditioning systems over the sampling probe stand, moving jointly with it in the lateral displacement version described on claims 6 and 7; and being the mentioned treatment and conditioning systems composed of a dust filter to hold the ashes and a cooling and/or sample moisture condensing system.

9. System according to claims 5, 6, 7, or 8, allowing the cleaning of the sampling circuit by means of countercurrent pressurised air (dust filter and sampling probe blowing) making the system autonomous between sampling periods.

10. System according to claims 5, 6, 7, 8 or 9 where the results obtained in the local measurements taken by the system itself, are transferred to the facility Control Room, to enable process monitoring and adjustment.

11. System according to claims 5, 6, 7, 8, 9 or 10 provided with combustion optimisation software (performance, pollutants generation, slagging, etc.) based on the results given by the system local measurements and eventually other plant operational data or results.

12. System according to the previous claims applied to combustion processes other than the ones contained in claim 1, and being more specific, those which use gaseous, liquid or solid fuel or mixtures of these, under presence of air, enriched air, and in general any oxidising agent.

13. System according to claims 1 to 11 applied to other industrial burners, in a global or individual way, as for example the ones mounted in process furnaces, clinker furnaces, metallurgic furnaces, toxic and dangerous waste incinerators or solid urban waste incinerators.

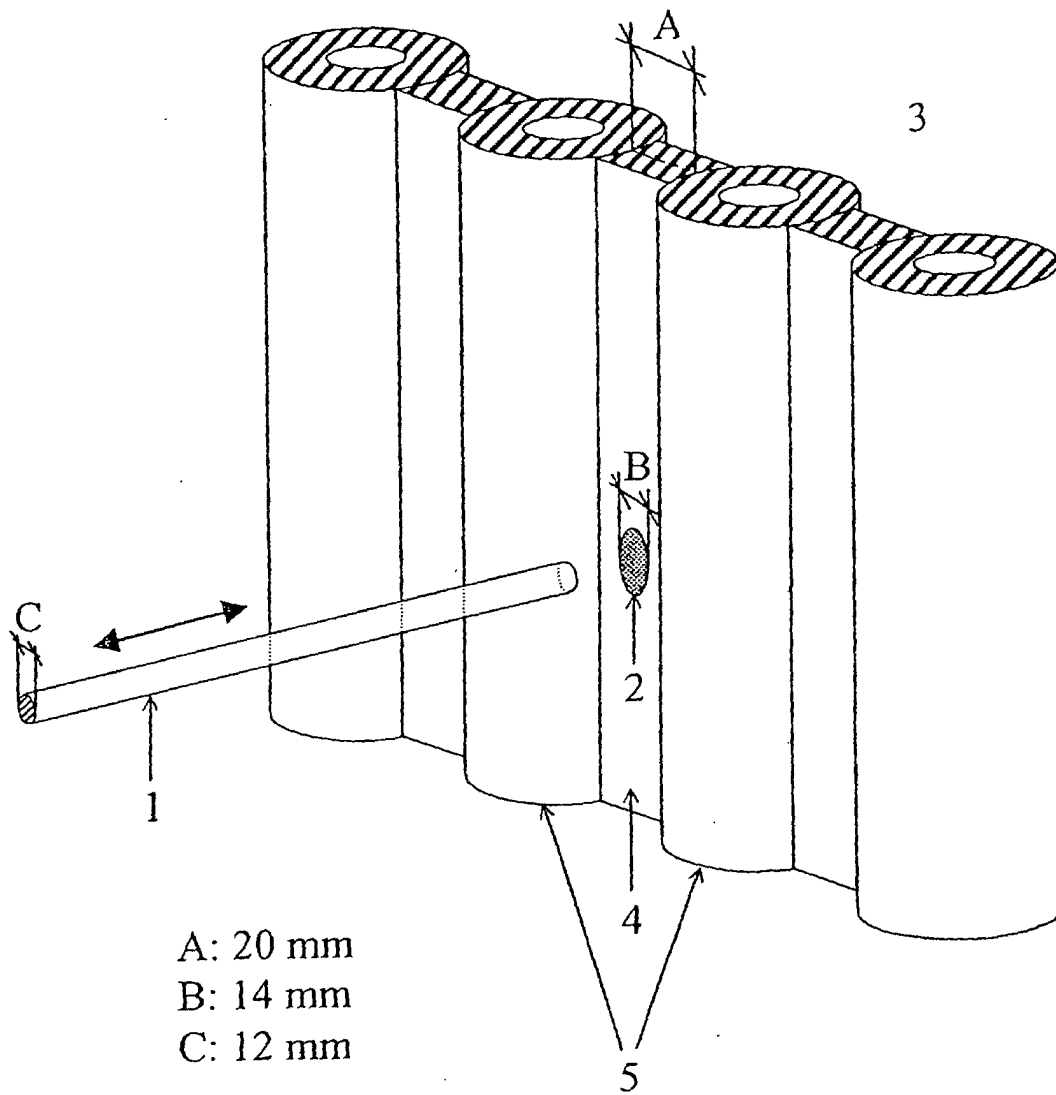


Fig. 1: System diagram (basic version)

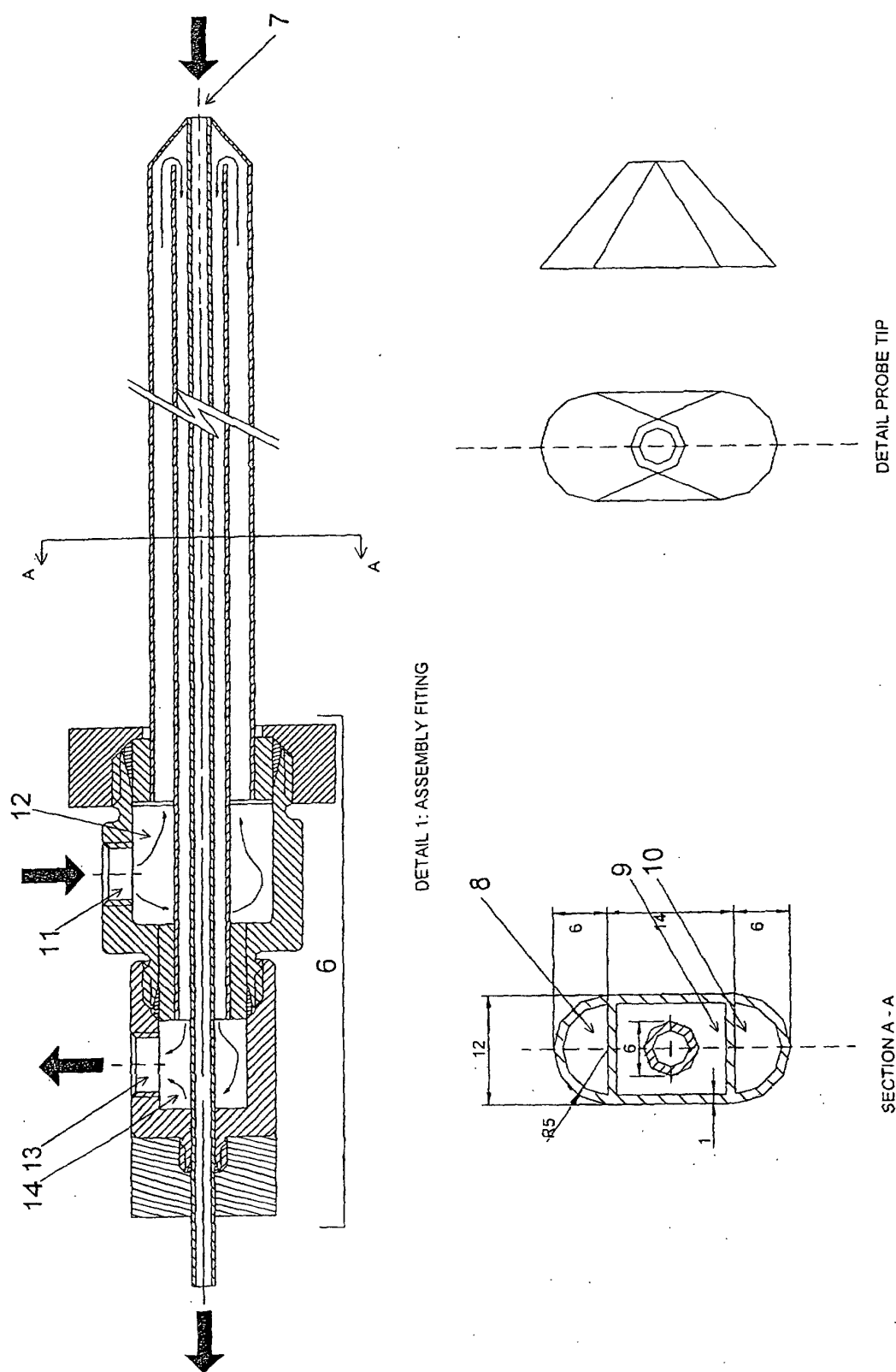


Fig. 2: Probe diagram, cooled version and for gas sampling (distances in mm)

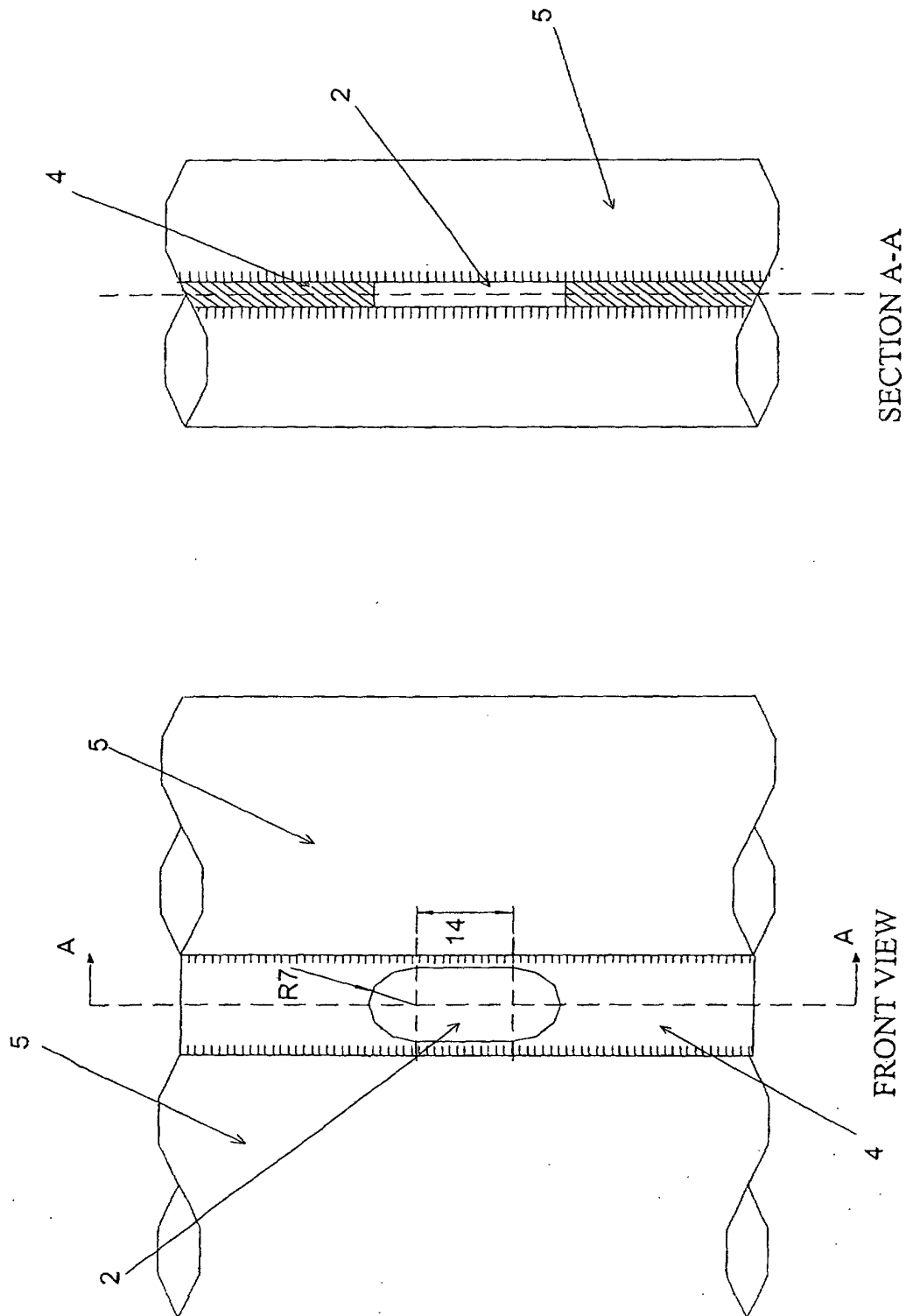


Fig. 3: Point of entry into the furnace (distance in mm)

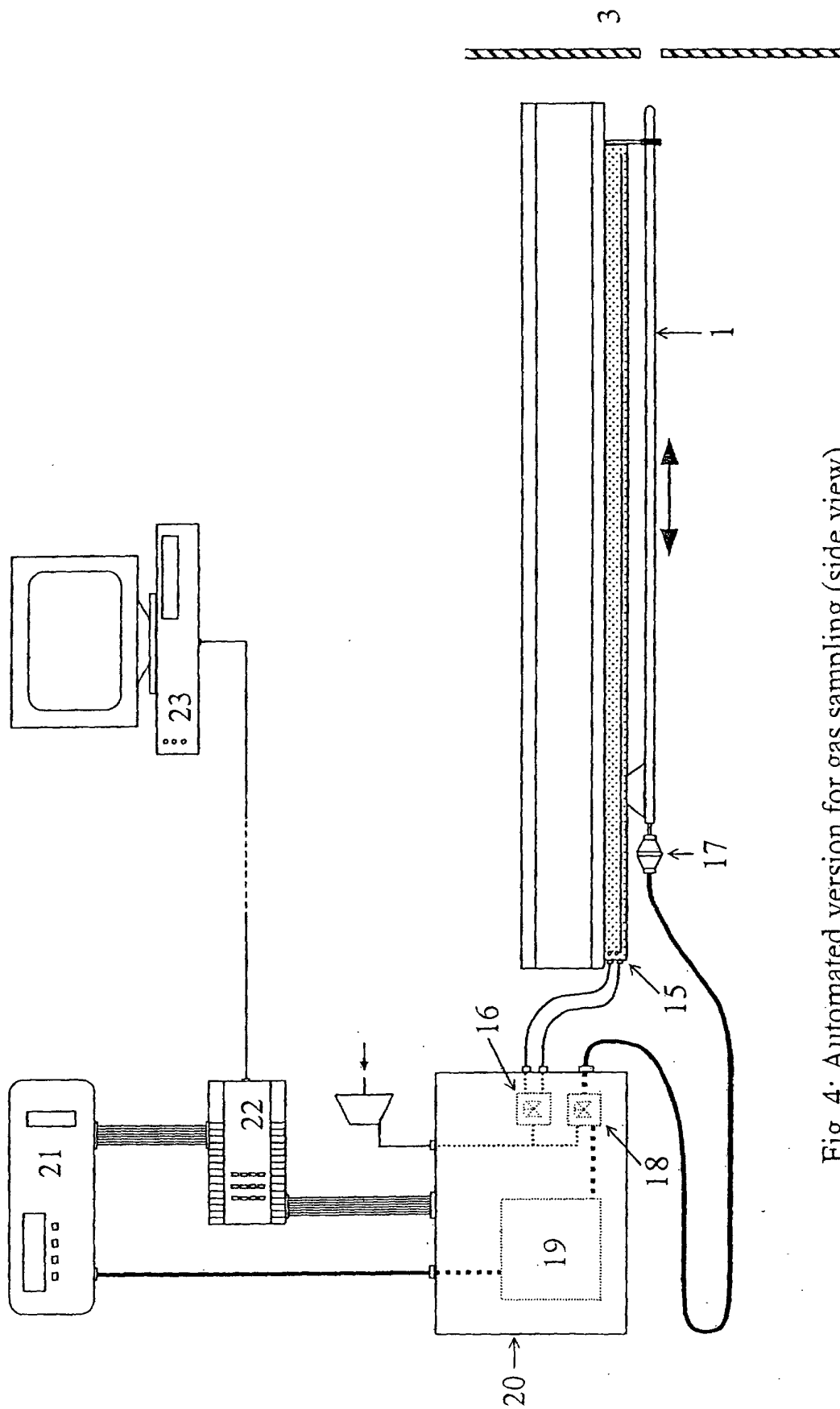


Fig. 4: Automated version for gas sampling (side view)

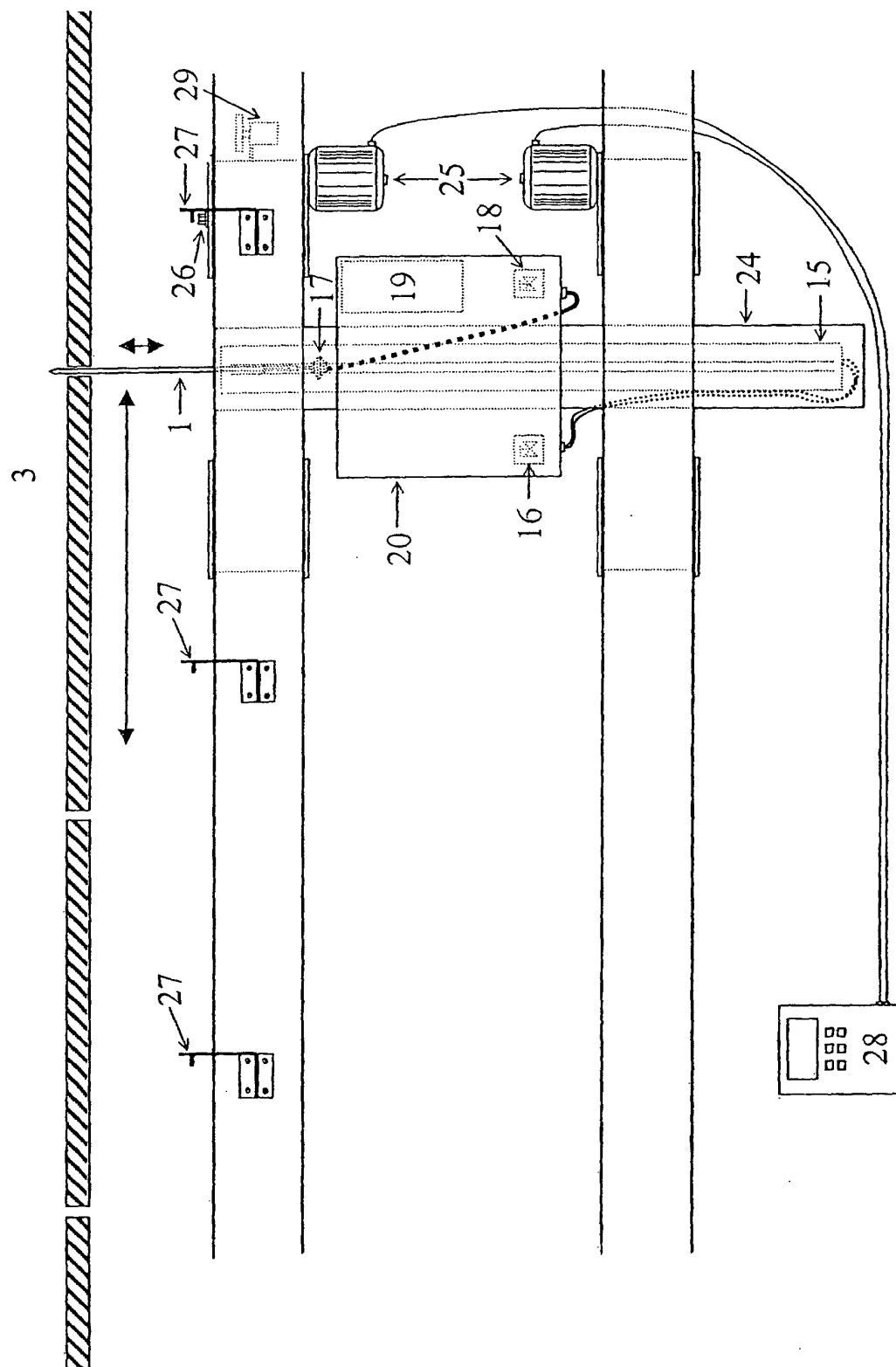


Fig. 5: Automated version for gas sampling with probe sideways and insertion - extraction displacements (top view)