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Continuous heating furnaces with chain link conveyor and inert gas equipment

By T. F. Kohlmeyer

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by T. F. Kohlmeyer*), Hagen

The increasing rationalisation and automation in the heat treatment of small parts led to the development of continuous heating furnaces with chain link conveyers. Continuous working particularly facilitates the inclusion of such furnace installations in a production line. For inert gas brazing, the continuous heating furnace is no longer to be considered a back number. Brazing plant acquired this importance because the brazed product leaves the furnace quite bright, and therefore free of oxide and grease, and can be varnished or subjected to some other surface treatment straight away.

Introduction

Furthermore, the chain link conveyer continuous heating furnace is particularly suitable for bright annealing of steel, noble metals, nonferrous metals and their alloys. The inert gas atmosphere must naturally be adapted to the purpose in each case.

Exogas, endogas (I), cracked ammonia gas (II) or high purity hydrogen (III) come up for consideration as inert gas. If, during heat treatment, moist protective gas already gives a satisfactory result as furnace atmosphere, protective gas production can take place direct in the furnace space. By embodiment of the protective gas generator in the furnace, the economy of the installation will be somewhat more favourable compared to equipments with separate gas generator. It must, however, be borne in mind that the production of protective gas requires introduction or removal of heat. Hence the built-in protective gas installation influences accurate temperature regulation of the furnace.

Furnace installations can often be designed for handling temperatures up to 1100° C. In addition to small parts, rods, tubes and sheets can also be handled with advantage. Even large pipes with lengths up to 10 m can be annealed successfully. As a rule, the output is 50 to 500 kg/h net.

The following report deals with a recently developed continuous furnace with chain-link conveyer, which permits bright annealing of chrome-nickel steels. The bright annealing plant was installed in a works for production of radiators of high-grade steel tubing. The measures for extensive automation which resulted are shown. The many possibilities of furnace installations with chain link conveyers are shown by means of these examples.

Statement of tasks

The annealing plant should be arranged in the production flow for manufacture of radiators. The following operations cover the whole production flow:

Drawing in the radiator into the covering tube;

Filling the tubes with insulating material (MgO) and closing the tube ends with stopping;

Compressing the filled tubes by reducing rolling;

Annealing;

Applying connnecting parts and soldering up;

Bending radiators;

Testing and stamping.

The stresses and rigidity should be eliminated by the preceding deformation. The radiators should not be distorted from the previous annealing and must leave the furnace bright. The closing stoppers should be burnt up by the annealing process, whence residues should not occur. The surface of the radiators should be so free of scaling after annealing that the fastening pieces should be able to be brazed on without more ado. For bending the radiator into the shape required in each case, it is important that the covering tube should be soft annealed and not sprung back.

The radiators prepared for annealing have a diameter of 8 mm and a length of 400 to 2000 mm. The material for the covering tube is stainless steel with the following alloy components:

$C \leqq 0.1$, $Si \leqq 1.0$, $Mn \leqq 2.0$,
Cr 18%, Ni 9%, $Ti < 5 \times \%\, C$.

The net output for tube radiators should be 130 kg/h, corresponding to about 500 m/h.

The completely automatic charging and removal equipment is included in the duty allotted. The individual radiators, coming with a certain cyclic regularity from the reducing rolling, are fed into the charging device and then passed on in sets to the conveyer belt. The annealed product that has been treated leaves the furnace in sets and must again be broken down into single units by the removal equipment in the cyclic regularity prescribed.

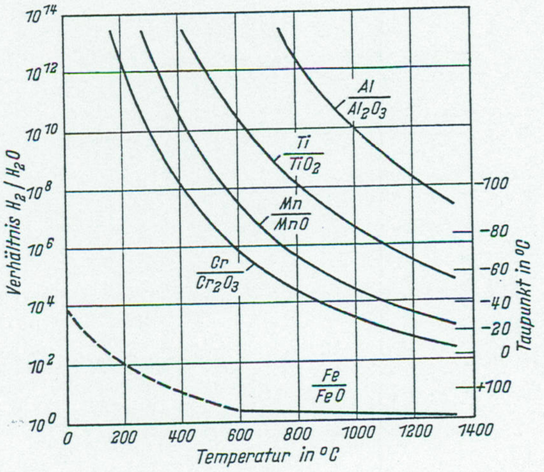

Fig. 1 **Temperature-dewpoint function of various metal/metal oxide equilibria**
Verhältnis = ratio; Temperatur = temperature; Taupunkt = dew-point

Consideration of reaction

To prevent unwanted oxidation of the tube radiator, the annealing must be carried out in an inert atmosphere, since stainless steels are also sensitive to carburising, as the corrosion resistance is thereby reduced; ammonia cracked gas comes up for consideration as furnace atmosphere. The protective gas must be very dry, to prevent oxidation. The permissible content of hydrogen in the cracked gas is determined by the equilibrium relationship between the ratios of H_2/H_2O and metal/metal oxide. The dew point must be lower than the most active element of the alloy steel. In figure 1, the various equilibrium conditions are shown as a function of the dew-point temperature.

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Austenitic chrome-nickel steel tube radiators are stabilised with titanium and hence particularly difficult to bright anneal (IV). Titanium has a much greater affinity for oxygen than chromium. Thus in the region in which chromium oxide is already unstable the formation of an oxide layer by TiO_2 is still possible. With an annealing temperature of 1100° C, a dewpoint of − 20° C is sufficient to prevent the formation of chromium oxide; on the other hand, a dewpoint of − 80° C requires the prevention of titanium oxide at this processing temperature. With a falling annealing temperature, the possibility of a reaction between hydrogen and the metals increases, so that for a temperature of 800° C a dewpoint of − 50° C or − 100° C is necessary. The reaction trend is, however, more sluggish with lower temperature. At about 300° C the speed of oxidation is so retarded by the oxygen combined with water vapour that oxidation practically no longer occurs. Free oxygen from the air acts as an oxidizer on the annealed product above 180° C. The tube radiators must therefore be cooled down in the furnace to a temperature of 150° C in an inert gas atmosphere.

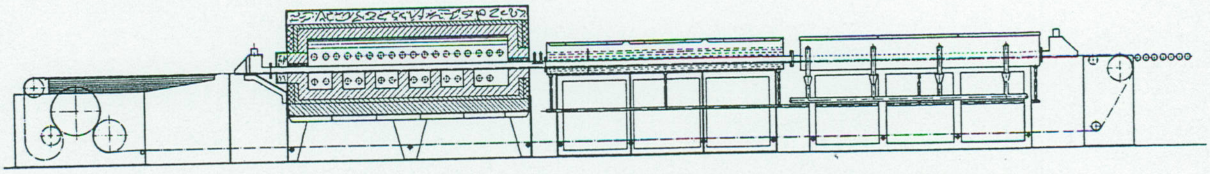

Fig. 2 Section of an electrically heated continuous heating furnace with chain link conveyer

The dewpoint of the protective gas, the annealing temperature level and the speed of heating and cooling the annealed product are decisive for the attainment of as bright a surface as possible in annealing titanium-stabilised chrome nickel steel radiators. To prevent too strong a growth of the oxide layer and the resultant colouring of the radiator, the furnace atmosphere must be extremely dry and have at the same time a high annealing temperature, also short heating and cooling times must be striven for. An oxide layer from about 250 Å units thickness is already visible from the matt or coloured appearance of the surface.

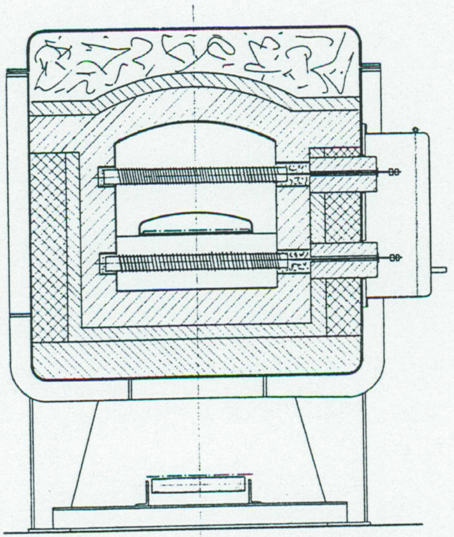

Fig. 3 Cross section on figure 2

Continuous heating furnace with chain link conveyer

The continuous heating furnace is a gastight type of construction, suited to operation with ammonia cracked gas as inert atmosphere. The installation comprises charging table with conveyer belt driving station, feed sluice, the heated portion of the furnace, the cooling zone, the outlet sluice, the belt guide station with extraction device, switching and control gear. Figure 2 and figure 3 show a longitudinal and a transverse section respectively of the electrically heated furnace installation.

The tubular radiators are automatically placed on the conveyer belt by a feed machine and continuously transported through the whole furnace installation. The speed of the conveyer belt must be able to be altered in dependence on the thickness of the condenser plates. The driving motor is therefore equipped with an infinitely variable drive (in the range of 5 to 30 m/h), so that the necessary dwelling time of the tube radiators in the furnace can be adjusted. In the driving station the driven roller has a particularly large diameter. Thus tension to ensure pulling round belt on driving drum will be kept small. The coefficent of friction between the drum and the belt is furthermore decisive for carrying along. The running surface of the drum is rubber-coated, to obtain favourable conditions.

The conveyer belt is subjected to the greatest stress in the installation. It is heated to 1100° C by passing through the heating zone and cooled down to about 100° C in the subsequent cooling zone. On the return run of the endless belt under the furnace, it is finally cooled to room temperature before it arrives in the furnace again. It can be calculated that, with continuous operation of the plant, the belt runs through the furnace about 3000 times in one year. Scaling of the belt is slight, as there is a strongly reducing atmosphere permanently in the furnace. The most important property for stability of the chain-link conveyer belt is resistance to heat, i. e. a load-carrying capacity at the temperature occurring in use.

A chain link belt of round wire with corrugated transverse rods and channel edge is chosen as conveyer belt. Owing to the corrugations of the transverse rods, the wire coils do not lie close packed, but are kept apart at a definite pitch. Reduction in width of the original 400 mm wide belt in the course of the work can therefore be prevented to a great extent. The use of alternately left and right hand twisted spirals contributed to the running properties, so that lateral play was kept within small limits. The belt is provided on each side with a gutter edge 20 mm high made of stamped metal

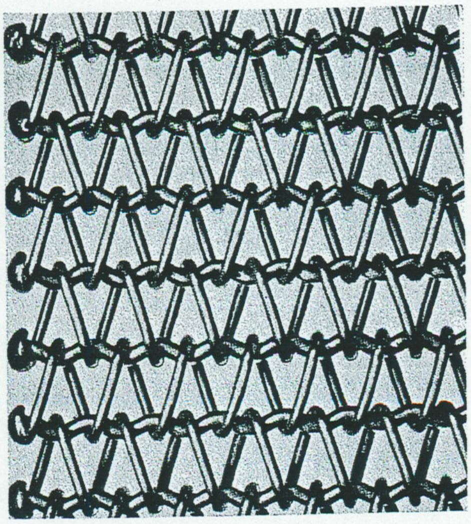

Fig. 4 Conveyer belt of round wire links

components, which made it possible to load the whole width of the belt, without risk of spillage of the radiators. As illustration, figure 4 shows a round wire component belt with corrugated transverse rods.

For the sake of higher output in connection with cleanliness of the atmosphere the furnace is provided with a gastight muffle. Therewith the harmful influence of the brickwork is kept away by the protective gas. Thus the Fe_2O_3 contained in the firebricks is prevented from being reduced to hydrogen and the dewpoint of the protective gas from deterioration to an unpermissible extent, from the formation of water vapour. If for example only 1 gr H_2O is given off from the brickwork the dewpoint of about 100 Nm^3 of protective gas is caused to deteriorate from $-90°$ to $-55°$ C.

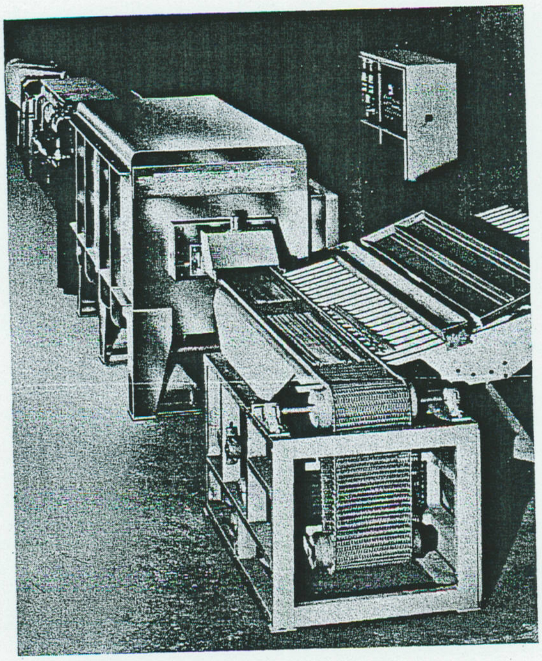

Fig. 5 Conveyer belt continuous heating furnace
In the foreground is the charging side with driving station and charging device

Through the embodiment of the muffle there results furthermore the advantage that the gas-filled furnace space remains small.

Cracked ammonia gas consists of 75% by volume of hydrogen and can form explosive mixtures with air. With the small furnace space volume there is, however, no danger from the inert gas, even if, owing to failure of the protective equipment in the furnace there occurs in the furnace a mixture of hydrogen and air which ignites.

The muffle is made of a heat-resistant chrome-nickel alloy and provided with a reinforced base. Supporting buttresses in the furnace walling prevent flexure of the muffle. Corrugations in the upper half of the muffle increase the stability. For free heat expansion the muffle is simply screwed gastight with the cooling zone and can expand freely through the inlet sluice. On heating up, an expansion of the muffle of over 50 mm has been observed.

Electric heating elements are arranged radiating freely above and below the muffle. The resistance wires are wound on ceramic carrying tubes, which are heavily loaded with a supporting length of 500 mm. Two heating coils are in each case assembled in hairpin shapes. These double heating rods can be readily exchanged from one side of the continuous heating furnace. An exchange of the heating elements is even possible during operation of the plant.

By the installation of heating elements also underneath the muffle, a large heating output can be accommodated. Appropriate arrangement of the heating coils produces very short heating times and uniform temperature gradients in the furnace space. Even very long tubular radiators do not warp during the annealing. It is favourable to the surface quality if the heading up speed is as high as possible. Hence the heat output is particularly concentrated on the intake side. The heating equipment is divided into two completely independent regulating zones, in which 45 kW are installed in the short heating zone and 30 kW in the following zone. The alloy with the composition 80% Ni and 20% Cr has been well proved as heating conducting material. With 70 volts supply, the heating elements give large heating conductor cross sections which, even under unfavourable working conditions, ensure long life. Great importance must be attached to accurate temperature regulation at the high working temperature of the annealing furnace, as the various furnace construction materials are in part thermally heavily loaded.

Thermocouple elements of the PtRh-Pt type are used as temperature sensing devices, as NiCr-Ni, or chromel-alumel, thermocouple elements do not ensure the necessary accuracy and safety at furnace temps over 1100° C. Fluctuations of the room temperature at the comparing place have a disturbing effect on the results of measurement. A comparison place corrector is therefore embodied.

Two-step action control is provided for the temperature control. In the measuring circuits of the temperature controller an electronic PID flyback is placed in circuit for adjusting the controller to the controlled system. The speed, stability and accuracy of the regulation are raised by the PID behaviour. A thermocouple element security against breakage serves for tell-tale device of the thermocouple element circuit.

The cooling zone connects up direct with the heated furnace zone. The tubular radiators must be cooled down to about 150° C, so that they no longer oxidize on exit into the air. On cooling down, the heat transfer with temperature difference, becoming smaller, is raised by radiation. Owing to the heat transfer process, the cooling zone is about twice as long as the heated furnace zone.

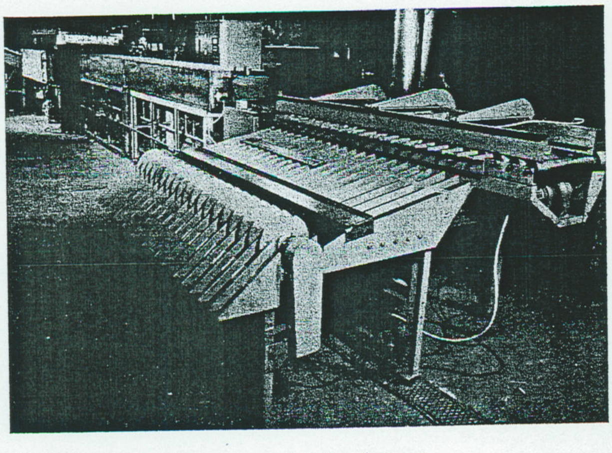

Fig. 6 Output side of continuous charging furnace
Right: roller bed that can be tipped
Left: breaking down roller, cooling zone in the background.

The cooling zone is divided into several sections, which consist of several sheet metal boxes with a double casing. Cooling water flows between the inner and outer walls, which is permanently led in afresh. Guide baffles and valves for distributing the cooling water, also overflow places, are so arranged that the tubular radiators are cooled down particularly quickly, after the annealing process. The surface quality for tubular radiators is further improved by the forced cooling. The internal lining of the watercooled chambers is of stainless steel.

sults. Splitting takes place in dependence on a nickel catalyst at a temperature of about 1000° C.

The gas volume is doubled by the splitting. The retorts are heated by electrical resistance elements. To reduce the power consumption, the heating chamber is provided with good heating insulation. The temperature in the heating chamber is measured with a thermocouple and the heating controlled by a regulator. The temperature regulator is provided with contacts for maximum and minimum working temperature. After exit from the retorts, the hot cracked gas in the vaporizer gives off the greater part of its sensible heat, whereby the necessary heat of vaporization is led to the NH$_3$. The cold cracked gas is led through a flowmeter of an adsorption device for further purifying and drying. The stopvalves afford the possibility of blowing off the cracked gas into the open air, which is necessary on putting the plant into operation.

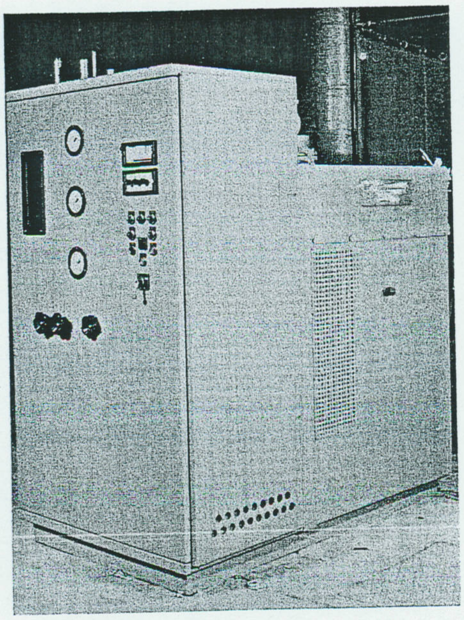

Fig. 9 Ammonia cracking plant

Figure 9 shows the ammonia cracked gas plant.

Figure 10 shows the theoretical equilibirium of the NH$_3$ residual content in the cracked gas in dependence on the temperature. As the dynamic reaction on cracking does not run on completely to the temperature-equilibirium, there remains a larger NH$_3$ residual content in the cracked gas than the equilibrium value. The actual residual content is affected by the gas pressure, and particularly by the duration of the period spent in the catalyst. The modern conception of the cracking plant showed favourable reaction conditions, so that the residual content only amounted to 50 ppm NH$_3$.

The moisture content in the cracked gas depends directly on the water content of the ammonia gas supplied and cannot be altered by the cracking process. Figure 11 shows the dependence of the water content in the NH$_3$ on the dewpoint of undried cracked gas produced therefrom.

The liquid ammonia is supplied with a moisture content of 0.05 % by weight of H$_2$O, whence results a dewpoint of −34° C.

The purity of the ammonia cracked gas for bright annealing titanium-stabilised chrome nickel steel is not satisfactory, so that an adsorber must be placed in circuit. Through the use of molecular filters (V) as adsorbers, H$_2$O and the residual content of NH$_3$ can be eliminated at the same time.

Figure 12 shows the diagrammatic layout of an adsorption plant for continuous drying and purification of cracked ammonia gas. The plant consists mainly of two containers filled with molecular screens which are connected with 4-way valves and furthermore from the regeneration system.

Whilst the cracked gas is being freed of its unwanted gas components in a molecular screen bed, the other molecular screen can be regenerated. By automatic switching over of the gas flow at definite time intervals, a continuous method of working is attained.

By regeneration is to be understood heating of the molecular screens to about 250° C, whereby the impurities are desorbed. After reaching the regeneration temperature, the bed is cooled with cool dry gas and is again ready for adsorption. A small amount of dried cracked gas is tapped off as scavenging gas during regeneration; care must then be taken that the liberated ammonia is flushed out. The generation system, in which gas is circulated to be heated or cooled, consists of gas blower, heating battery, gas cooler, water separator and condensate runoff. For the cooling process, the heating battery is simply switched off by a time relay.

The outgoing flushing gas is blown off into free air through a flowmeter.

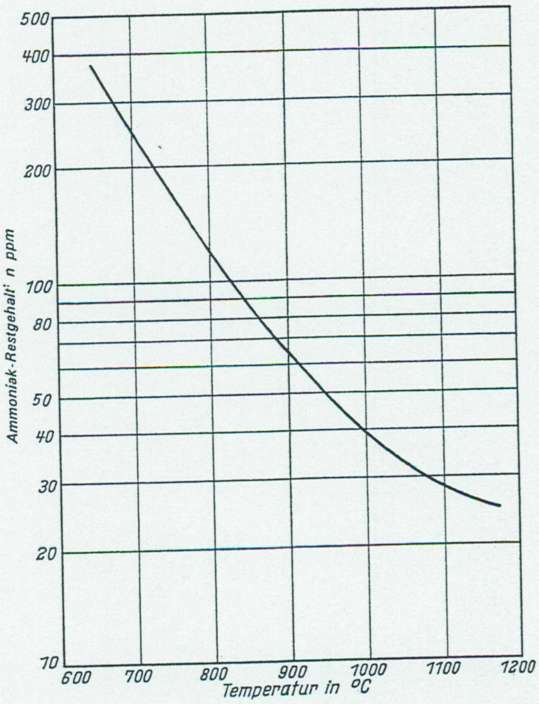

Fig. 10 Equilibria for the NH$_3$ residual content, dependent on temperature

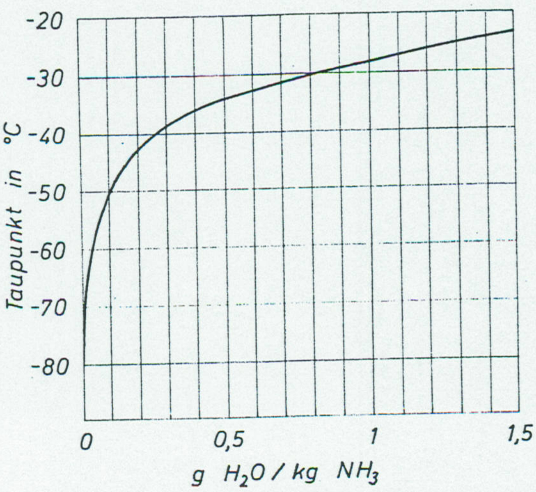

Fig. 11 Water content in liquid ammonia and dewpoint of the undried cracked gas produced therefrom

The furnace installation is provided with a sluice on the inlet and outlet side. They are not tight-closing chambers, but devices with several heat resistant curtains, which cover the furnace cross section. In addition, a vertically adjustable door is fitted. The requirement for protective gas is dependent on the free furnace cross section, so that the best possible sealing must be attempted. The protective gas is several times lighter than air and therefore has a tendency to rise rapidly upwards. At the exit opening of the sluice the air forces its way up from below and forces the protective gas flow upwards. Flat cross sections require a considerably less amount of protective gas than high cross sections with the same surface area. The expenditure of protective gas is thus not only dependent on the number of surface units, but also on the ratio of width to height of the cross section.

The whole amount of protective gas is led to the furnace space by a single connecting point. This point lies between the heated portion of the furnace and the cooling zone. To obtain controlled distribution of the protective gas in the intake and outlet direction, the lead-in consists of two mains with flow meter and regulating valve. The protective gas is blown by jets in opposite directions, so that two flows exist in the furnace space. Careful consideration of the phenomena which arise from the direction of flow in the furnace atmosphere shows how important this factor is for the bright annealing operation. The protective gas, fed in cold, is on the one hand pressed towards the intake sluice through the annealing space and, on the other hand, through the cooling zone to the outlet side. The protective gas in the annealing muffle flows against the direction of feeding-in of the products being annealed and is heated by the conveyor belt and tubular radiators to 1100° C. Thus the conveyor belt and the tubular radiators cool down simultaneously before they arrive in the cooling zone. The protective gas assumes the set temperature of the furnace space in the annealing zone and acts in a reducing capacity on the chrome-nickel tubular radiators. In the heating zone of the furnace the impurities on the products to be annealed and the conveyer belt are removed by the protective gas. By impurities are to be understood oxygen and moisture, in addition to oils, greases or drawing material residues on the tubular radiators. The plastic stoppings, which close the ends of the tubular radiators from a previous processing step, must also be removed. All impurities (including the stoppings) dissolve and vaporize in the heating up zone of the furnace, through the effect of temperature and furnace atmosphere. There remain no residues on the surface of the tubular radiators. The gaseous impurities are entrained by the protective gas flow, led to the outlet sluice and there burnt away. The flow of protective gas, which is directed through the cooling zone to the outlet sluice, is not affected by the impurities.

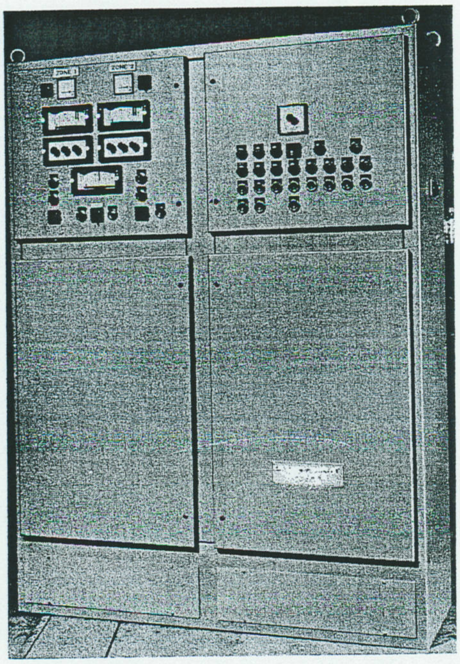

Fig. 7 **Switch cabinet for continuous heating furnace with automatic transporting equipment**

The extreme demands on the furnace atmosphere in the cooling zone to obtain satisfactory bright annealing, can accordingly be fulfilled.

On the outlet side of the furnace plant there is an automatic extraction device for the chain link conveyer. Adjoining this is installed a completely automatic extraction device. The extraction device comprises a roller bad driven by a driving motor. The whole roller bed can be tipped laterally by an electric adjusting device. Furthermore, a storage place and a singling out roller for the tubular radiators belong to the extraction device. The tripping process for the train of rollers is automatically triggered off by a protected switch. A contact flap on the train of rollers can be adjusted in dependence on the length of the tubular radiators.

The cyclic time is steplessly regulated for breaking down into single units the tubular radiators tipped out from the storage device. A counter for the rate of breaking down into single units sends out a pulse for controlling the charging device on the intake side of the furnace. Figures 5 to 7 should serve for better illustration of the whole furnace plant.

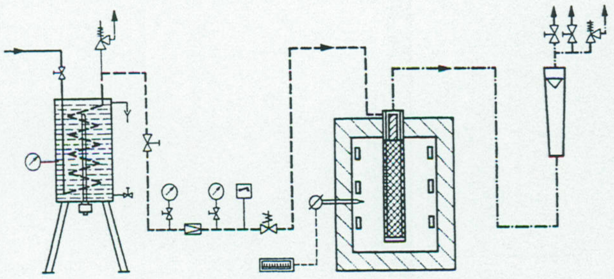

Fig. 8 Construction of an ammonia cracking plant

———— Liquid NH_3

– – – – Gaseous NH_3

—·—·— Cracked gas $\left\{ \begin{array}{l} 75\%\ H_2 \\ 25\%\ N_2 \end{array} \right.$

Protective gas producer

The method of operation of an NH_3 cracked gas plant is shown diagrammatically in figure 8. Liquid NH_3 is led to a vaporizer, in which conversion to the gaseous phase takes place. Thereby about 1.3 Nm^3 of ammonia gas arises from 1 kg NH_3. A safety valve prevents an impermissible rise in pressure and thus protects the vaporizer, if the pressure reducers for the liquid NH_3 are not working satisfactorily. The gaseous NH_3 is then led through a pressure reducer to a constant working pressure of 0.5 atmospheres. The ammonia gas is led through a solenoid valve and flowmeter to the reaction retorts.

The flow volumes can be controlled through valves and by flow meters, so that a regular admission to the individual retorts is ensured. A pressure telltale protects the plant from excess pressure and acts on the solenoid valve, so that the gas input is automatically shut off.

In the reaction retorts, the gaseous ammonia is endothermally split, as in the equation

$$2\ NH_3 = 3H_2 + 1\ N_2$$

to the temperature-dependent equilibrium, whereby a gas of about 75 % by volume of H_2 and 25 % by volume of N_2 re-

Figure 13 shows the adsorption plant for drying and purifying cracked ammonia gas with automatic valve switching over. Before the drying, the moisture content in the cracked gas amounts to 0.2 g H_2O/Nm^3, which corresponds to a dewpoint of −34° C. The NH_3 residual content after cracking is about 0.04 g NH_3/Nm^3, corresponding to 50 ppm. From the quantitive relationship of the adsorbates H_2O to NH_3, such as 0.2 to 0.04, it is obvious that adsorption capactiy for water vapour is essential in purification.

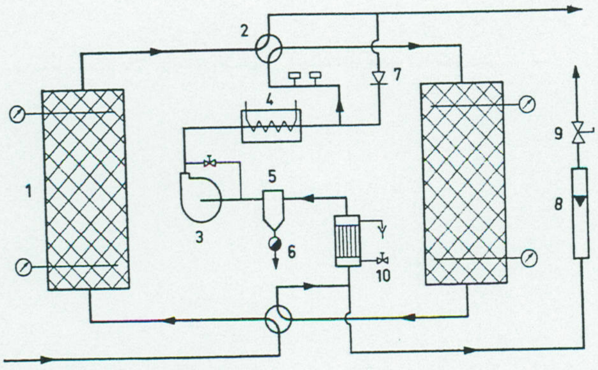

Fig. 12 Construction of an adsorption plant

(1) Molecular screen; (2) 4-way valve; (3) Blower; (4) Heater; (5) Water separator; (6) Gas-cooler; (7) Reflux valve; (8) Flow-meter; (9) Regulating valve; (10) Cooling water valve

In the drying of cracked ammonia gas with the aid of molecular screens, a dewpoint of less than − 90° C (below 0.1 ppm H_20) is attained. At the same, the NH_3 residual content in the cracked gas is reduced to less than 1 ppm in the adsorption plant.

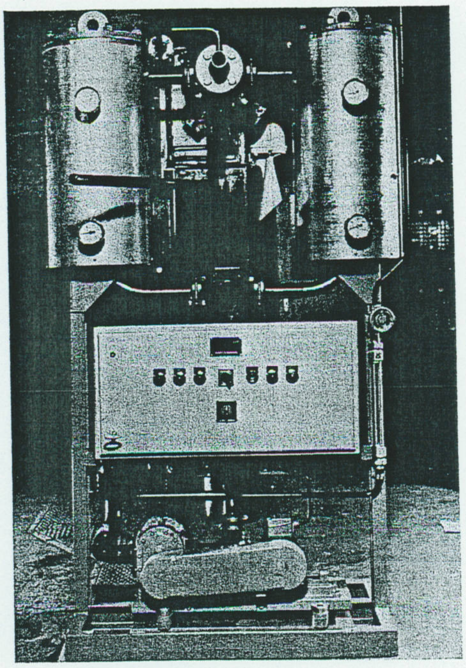

Fig. 13 Adsorption plant

Safety equipment

In annealing with cracked ammonia gas as furnace atmosphere, careful safety measures must be taken to ensure that no risk of explosion exists. The strongly reducing annealing gas, with a hydrogen content of 75 % by volume, can form highly explosive mixtures with air. The explosive range is particularly wide, with 4 to 72 % by volume of H_2 in air. In addition, the lower limit for ignition temperatures is low, at 530° C.

Owing to the embodiment of the annealing muffle, the conveyer belt furnace has only a small furnace volume filled with protective gas. In case a protective gas and air mixture forms and ignites, this leads to the immediate deflagration of the whole mixture. The resultant effect is a sudden rise of pressure and temperature. The danger in the annealing furnace lies in the rise in pressure which, however, through large openings with elastic curtains at the inlet and the outlet side, can slowly die down, without causing any damage.

In addition, some locking devices and safety switches are provided, which ensure increased safety. A solenoid valve in the inlet piping for protective gas only opens when a temperature above 700° C exists in the furnace space. The protective gas supplied burns with flame formation in the furnace and forces the air out of the furnace space. Furthermore there is installed in the furnace plant an automatic nitrogen flushing equipment. A flash battery with compressed nitrogen is so connected that, on disturbance in the furnace or the protective gas plant, the protective gas supply is cut off and nitrogen introduced to scavenge the furnace space. The scavenging system also works automatically in case of failure of the power supply. Safety is also increased by scavenging with nitrogen before putting the furnace into operation.

The emerging protective gas is burnt away at the inlet and the outlet sides. Safety burners with automatic flame check serve for ignition.

Control devices for checking the furnace temperature regulation and the cold water flow are installed for the protection of the furnace.

Summary

The tubular radiators leave the annealing plant clean and bright. Further requirements from the annealed products, such as soft annealing for example, are satisfactorily fulfilled. Predetermined values for the heat treatment, such as annealing temperature, heating up and holding times, also speed of cooling, are adhered to. The temperature of the tubular radiators on leaving the cooling zone only amount to 80° C.

The nominal output of 130 kg/h could be further raised by about 50 %. Favourable use data are afforded by the modern design of annealing plant. Thus the specific power consumption is extremely good at 0.4 kW/kg. Cooling water consumption is about 1 m^3/h and the protective gas consumption of the furnace installation was very economical with 12 Nm^3/h. The favourable running costs make possible satisfactory heat treatment of the tubular radiators with optimum economy.

It was shown by means of the equipment introduced in this report that the continuous heating furnace with chain link conveyer belt is well suited for bright annealing of chrome nickel steels which are stabilised with titanium, with an extremely pure protective gas atmosphere. The practical measures specially adopted for this were described.

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