The theoretical basis, the technique of preparing protective atmospheres, the apparatus for producing protective atmospheres, and their use in heat treatment are described in [1-11, 21]. At the present time, the use of protective atmospheres is standard procedure in heat treatments used abroad [3, 4].

In machine construction plants, one uses endothermic atmospheres prepared by cracking natural gas (α = 0.25) with the GIAP-3 catalyst. However, endothermic atmospheres and the method of regulating the carbon potential by the dew point have several drawbacks [7, 8]*:

1. Endothermic atmospheres are explosive, and therefore cannot be used for high temperature tempering.

Sometimes the use of endothermic atmospheres requires that gases be blown through, and this complicates the heat treatment operation and makes it more expensive.

2. Endothermic atmospheres have low carburizing capacity and therefore cannot be used for case hardening. To improve the case hardening properties of these atmospheres one adds gas, and this makes it impossible to regulate the carbon potential by the dew point.

The method of case hardening in furnace atmospheres with variable carbon potential complicates the heat treatment, and the decrease of the carbon potential to the optimum value (0.8-0.95% C) only during the cooling process preceding quenching decreases the strength of the treated parts by 25-30% [18].

3. The control of the carbon potential by the dew point during nitrocementation is even more complicated because the addition of ammonia increases the carburizing rate.

4. A relationship between the carbon potential of the endothermic furnace atmosphere and the dew point exists only when the temperature of the furnace remains constant. The necessity of correcting the dew point to preserve a given carbon concentration in steel at different furnace temperatures complicates the system of regulating it by the dew point and requires special equipment.

The method of direct control of the carbon potential by carburization of a special indicator makes it possible to control the carburizing capacity of any atmosphere containing carbon, which makes this method very promising.

Different apparatus used abroad for direct control and regulation of the carbon potential are described in [4, 8, 12, 19-21].

Apparatus for direct control have also been constructed in this country [13, 14]; one of these is used at the Chelyabinsk Tractor Plant.

Infrared gas analyzers are being used at home and abroad. These gas analyzers make it possible to measure very precisely (with an error of 2-5% of the highest reading of the indicator) the amounts of CO, CO₂, and CH₄ in protective furnace atmospheres [19-22]. The operation of these devices is based on the optical-acoustic method, which consists of the absorption by each component of the mixture of a part of the discontinuous infrared radiation corresponding to its absorption spectrum. The energy of acoustic oscillation induced by this absorption is proportional to the concentration of the component.

*The method of regulating the carbon potential requires further checking. (Editor's note).
The high selectivity of the method makes it possible to determine the components of gaseous mixtures containing CO, \( \text{CO}_2 \), \( \text{CH}_4 \), \( \text{N}_2 \), \( \text{O}_2 \), and \( \text{H}_2 \) in any ratio.

These apparatus can be used in automatically regulated systems for any amounts of carbon in the atmosphere. Mass production of these apparatus was organized by the SKB of Analytical Apparatus, Academy of Sciences USSR (27 models) and by the Listianskii OKB branch of the State Automation Committee of the Soviet of Ministers of the USSR on chemistry [22].

The nonexplosive nitrogen atmosphere free of \( \text{CO}_2 \) and \( \text{H}_2\text{O} \) is more promising and should be used in place of endothermic atmospheres [8]. Small amounts of gaseous hydrocarbons can be added to make it a carburizing atmosphere [1, 9, 15, 20].

The method of preparing nitrogen atmospheres with "molecular sieves" is being checked at NIITAvtoprom.

It was shown in [3, 8, 9] that it is not desirable to prepare nitrogen atmospheres by oxidation of gaseous hydrocarbons with \( \alpha = 0.5-0.9 \) (exothermic atmospheres) and then remove \( \text{CO}_2 \) and \( \text{H}_2\text{O} \) by passing them through ethanolamines and silica gel, or to prepare nitrogen atmospheres by purifying exothermic atmospheres and technical nitrogen by blowing them through red hot coal.

The preparation of protective atmospheres by cracking natural gas with technical nitrogen [16] is very interesting but requires further study. Nitrogen atmospheres are prepared at metallurgical plants by removing oxygen from technical nitrogen with dissociated ammonia. An apparatus for this purpose with an output of 200 \( \text{m}^3/\text{h} \) which was developed by Giprometiz has been used for several years at the Leningrad Steel Mill [17, 3].

A large plant for the production of nitrogen atmospheres by catalytic removal of oxygen from technical nitrogen by dissociated ammonia has been constructed by Stal'proekt and is presently operating at the Novo-Lipetsk Metallurgical Plant.

This method of preparing a nitrogen atmosphere is also logical because of its low cost. According to Stal'proekt, the cost of nitrogen protective atmosphere prepared by this method depends on the amount of oxygen in the initial technical nitrogen and on the amount of hydrogen in the final protective atmosphere. The approximate cost of the protective atmosphere consisting of 5\% \( \text{H}_2 \) + 95\% \( \text{N}_2 \) is (in kopeks/\( \text{m}^3 \)):

\[
\begin{array}{|c|c|}
\hline
\text{O}_2, \text{N}_2 & \text{cost} \\
\hline
7\%, 93\% & 1.9 \\
3\%, 97\% & 1.1 \\
1\%, 99\% & 0.8 \\
0.02\%, \text{rest } \text{N}_2 & 0.65 \\
\hline
\end{array}
\]

The cost of exothermic atmospheres purified with ethanolamines and silica gel is 1.6-2.2 kopeks/\( \text{m}^3 \), that purified by blowing through red hot coal is 2.7 kopeks, and that of endothermic atmospheres is 1.4 kopeks [8].

Comparison of the costs of nitrogen atmospheres calculated by Stal'proekt for gas producing plants with an output of up to 3000 \( \text{m}^3/\text{h} \) with the costs calculated by Giprometiz [17] (the atmospheres consisting of 96.5\% \( \text{N}_2 \) + 3.5\% \( \text{O}_2 \) cost 1.6 kopeks/\( \text{m}^3 \) and the atmospheres consisting of 99\% \( \text{N}_2 \) + 1\% \( \text{O}_2 \) cost 1.2 kopeks/\( \text{m}^3 \)) for plants with an output of 200 \( \text{m}^3/\text{h} \) indicates that the cost of these atmospheres is directly proportional to the size of the plant. Consequently, the greatest economy in using technical nitrogen for the preparation of protective atmospheres in machine construction plants would result from the production of technical nitrogen as a byproduct of oxygen producing plants.

It should be noted that a nitrogen atmosphere can be used not only for heat treatment but also for various processes in the chemical industry (for example, in the production of dyes and rubber tires, for the transportation of explosive powders, and in many other branches of the chemical industry [2]).

The obvious advantage of centralizing production and distribution of protective nitrogen atmospheres leads us to recommend such a plan for wide use in the machine construction industry and the use of nitrogen atmospheres for heat treatment.

Obviously, in each particular case one should check the logic of creating central plants for the production of nitrogen atmospheres as a byproduct of oxygen producing plants.