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SUMMARY

This paper gives a brief analysis of the factors determining the efficiency of underground gas storages as the means of meeting variations in gas consumption. The author describes a method of determining the necessary capacity and optimum productivity of storages, the suitable geological conditions and methods of prospecting and exploring for underground storages ; and the results of a theoretical study of gas hydrodynamic character in connection with underground gas storage are briefly stated. The first results of experimental gas and air injections into underground storages in the USSR are also described.

RESUME

Le présent mémoire est une brève analyse des facteurs qui déterminent l'efficacité des stockages souterrains pour faire face aux variations de la consommation. L'auteur décrit une méthode de détermination de la capacité nécessaire des réservoirs et de la cadence la plus favorable de soutirage. Il décrit les conditions géologiques ainsi que les méthodes de prospection et d'exploration des stockages souterrains ainsi que les résultats d'une étude théorique au sujet de la dynamique des systèmes eau-gaz qui a été effectuée en relation avec les problèmes du stockage souterrain du gaz. L'auteur décrit les premiers résultats des expériences d'injection d'air et de gaz effectuées en URSS.

THE PROBLEM OF UNDERGROUND GAS STORAGE IN THE USSR

N. S. Erofeev, USSR

I INTRODUCTION

There are variations in gas consumption by industrial enterprises and especially utility and domestic consumers. To meet the requirements of all the consumers it is necessary to have stand-by capacities for gas production and transportation or storages near consumption regions which could ensure conservation of gas surpluses during off-peak periods and their withdrawal during peak-load periods.

Technical-economic calculations and already existing experience of a number of countries show that construction and operation of underground gas storages is the most rational means to meet seasonal variations of gas consumption by large industrial centres. The use of depleted gas or oil fields for this purpose, if they are situated relatively near consumption regions, is the most advantageous way. If there are no such fields near consumers one has to construct storages in porous aquifers.

However, the construction of gas storages in aquifers is a complicated technical problem; it requires high expenditure, therefore this method can be economically justified only in some cases.

Profitableness of underground gas storage depends on numerous factors of great variety. The most important of them are :

— degree of gas consumption irregularity;
— capacity and length of the gas main;
— distance between the gas storage and the place of consumption and the gas main;
— geological and field features of the reservoir chosen for gas storage (trap reliability, collector permeability, reservoir pressure, actual capacity etc.).

In the USSR work on underground gas storage has been begun only a few years ago. For this time interesting economic investigations making it possible to determine the necessary parameters of underground gas storages have been carried out; a great volume of exploring work has been done which resulted in finding and exploration of a number of favourable structures and areas; the theory and hydro-gas-dynamic principles of storage construction in aquifers have been worked out; experimental injections of gas and air have been carried out under various geological conditions.

II ECONOMIC CRITERIA DETERMINING THE PARAMETERS OF UNDERGROUND GAS STORAGES

Variations of gas consumption depend on the type of the consumer. Utility and domestic consumers cause the greatest seasonal variations, large industrial enterprises cause lesser ones.

Evidently the degree of seasonal irregularity depends on the proportion of various consumers. However the analysis of average for a number of years on large consumption regions shows coinciding results.

Irregularity factors (the ratio of gas consumption for a given month to average annual consumption for a month) for Kiev, Moscow and the USA (for 1955) are given in Table 1.

Table 1.

Factors of Gas Consumption Irregularity for Months

Months	Regions		
	Kiev	Moscow	USA
January	1.29	1.22	1.27
February	1.28	1.31	1.34
March	1.18	1.21	1.24
April	0.97	0.99	1.035
May	0.82	0.75	0.845
June	0.76	0.70	0.785
July	0.74	0.69	0.73
August	0.77	0.74	0.74
September	0.79	0.82	0.76
October	0.95	1.0	0.88
November	1.15	1.22	1.06
December	1.33	1.36	1.34

Storage capacity necessary to meet seasonal variations of gas consumption can be calculated by the formulas:

$$V = \frac{\Sigma K > 1 - n > 1}{12} \cdot 100 \quad (1)$$

$$\text{or } V = \frac{n < 1 - \Sigma K < 1}{12} \cdot 100 \quad (2)$$

where V is the necessary actual storage capacity in % to annual gas consumption.

$K > 1$ are irregularity factors exceeding 1.
$n > 1$ is the number of factors exceeding 1.
$K < 1$ and $n < 1$ are the same indices less than 1 respectively.

The required storage capacity for the cases given in Table 1 is as follows.

Table 2.

	By formula 1 %	By formula 2 %	Average %
For Kiev	10.25	10.0	10.12
„ Moscow	11.08	10.91	11.0
„ the USA	10.67	10.5	10.6

The character of gas consumption variations determines not only necessary actual storage capacity but also its deliverability.

Besides seasonal variations there are day variations of gas consumption. Factors of day irregularity reach 1.6—2.0 as compared with average day consumption during the year.

Technical-economic calculations have showed that there exists an optimum irregularity factor under which the cost price of storage is minimum. Creation of conditions under which wider variations would be met causes a considerable increase of storage cost price.

For the analysed cases such an optimum factor is 1.35 corresponding to the maximum index of seasonal irregularity. The growth of the cost price of additional stored gas is shown in Table 3.

Table 3.

Growth of Cost Price as "K" Value Increases						
Irregulatity factor	1.35	1.40	1.45	1.50	1.55	1.60
Cost price of additional stored gas (in % to the cost price under K = 1,35)	100	115	153	178	255	468

Taking into account the coincidence of results for various conditions when designing and constructing underground gas storages, we consider it possible to assume:

— necessary actual storage capacity to be equal to 10—11 % of annual gas consumption by a large industrial region or town;
— storage deliverability to be equal to 35—40 % of average day consumption for a year.

A comparative analysis on the basis of gross technical-economic indices of underground gas storage efficiency depending on the capacity and length of a gas main permitted to draw the following conclusions:

— the efficiency of underground gas storage operation increases as gas main capacity rises and especially as gas main length increases;
— for most cases, gas main having the length up to 200 km, one should provide stand-by capacities for gas production and transportation and when gas mains have greater length one should construct underground gas storages if possible;
— in such cases the economy obtained by underground storage operation by far exceeds the expenditure on their construction. For example, for a gas main, having the length of 1000 km and the capacity of 10 million cu.m. per day, the economy exceeds the expenditure on underground gas storage construction 10 times.

In many cases, gas mains having great length and capacity, underground storage efficiency remains even when the storage is rather far from the consumer. For a gas main, having the length of 1000 km. and the capacity of 5 million cu.m. per day, high efficiency remains even when the distance between the storage and the consumer is 200 km.

Technical-economic investigations of the efficiency of underground gas storage were carried out in the Institute »Ukrgiprogas». Their results were published in a number of its works.

The obtained conclusions and worked out criteria are used in the USSR when prospecting and exploring structures favourable for underground gas storages.

III GEOLOGICAL CONDITIONS AND METHODS OF WORK ON PROSPECT AND EXPLORATION OF UNDERGROUND GAS STORAGES

More than 75 % of gas produced in our country is to be consumed by towns and industrial centres situated far from gas and oil fields. Therefore to meet seasonal variations of gas consumption, the main efforts are directed at the search for structures favourable for construction of underground storages in aquifers.

Prospecting and exploring work is carried out on a large scale under various geological conditions. It is directed at the search for local anticline structures and well permeable water-bearing intercalations overlaid with clay strata of sufficient thickness.

For the majority of regions with the largest gas consumption the geological conditions are little favourable.

In this connection the limit parameters determining the suitability of an object (the amplitude and dimensions of the structure, the depth, thickness and permeability of the stratum) are not established.

Structures with the amplitude of 12—15 m and strata lying at the depth of 800—900 m and 150—200 m. are being explored.

The thickness of clay overburdens varies from several metres to 100—150 m. All the strata being prospecting are represented by sand and sandstones, their permeability ranges from 0.5—1.0 darcy to several darcies.

Serious obstacles are caused by the low stability of sand streaks lying at small depth (200—300 m.). To prevent sanding up one has to provide wells with special filters. On one of the areas exploration of a stratum represented by cracked limestone is planned.

On one of the areas a sand lens lying in clay Devonian strata is prepared for experimental gas injection. The maximum thickness of the sandstone is 15 m., porosity is 25 %, permeability is 0.4—0.5 darcy, depth of lying is 745 m., initial stratum pressure is 78 atm.

Experimental withdrawal of 2000 m³ of water caused pressure drop in the lens by 5 atm.

Experts believe that an underground storage constructed in such lenticular sandstone (if one succeeds in drying it completely) will have a number of operating advantages.

Prospecting and exploring work is carried out in the following sequence:

- — study of general geological data of the region with large gas consumption, search for structures by means of seismic prospecting and drilling of profiles of shallow wells;
- — checking and study of the chosen structures by means of drilling of a network of shallow structural wells;
- — exploration of the aquifer by means of drilling and special testing of exploratory wells;
- — experimental gas injection.

Practice has shown that usual exploration by means of drilling of wells is insufficient for the preparation of an underground gas storage.

To obtain a quantitative characteristic of the aquifer and its overburden within the limits of a future underground storage special methods of well testing called hydroexploration have been developed and are used. The essence of these methods is that after creation of a system of wells uncovering the stratum being explored and the overlying permeable stratum, a series of tests on water withdrawal from some wells and observation of the pressure in other ones is carried out. On the basis of these tests aquifer conditions, the degree of communication of different sections, absence of overburden leakage, averaged numerical values of main stratum parameters-permeability and pressurebearing characteristic are determined.

Recently a successful test of area stratum exploration by means of injection of a small air quantity (200—250 thousand cu.m.) by usual compressors in a well and of observation of levels in other wells was carried out. This method is especially valuable when exploring wellpermeable thick acquifers where it is difficult to cause pressure changes, sufficient for observation, by means of water withdrawal.

In the USSR since 1957 750 shallow structural test wells and 156 exploratory wells have been drilled for prospecting and exploring of underground gas storages; area »hydroexploration» has been carried out in five structures.

IV ABOUT HYDRO-GAS-DYNAMIC PRINCIPLES OF CONSTRUCTION OF UNDERGROUND STORAGES IN AQUIFERS

Complex exploration, design and construction of underground gas storages in aquifers required special theoretical investigations and solution of a number of hydro-gas-dynamic problems. Such investigations are carried out in the All-Union Scientific Research Institute for Natural Gas (»VNIIGAS») and in the Academician Gubkin Moscow Institute of Oil-Chemical and Gas Industry (»MINKH & GP»). The results of these investigations were published in a number of works, the list of which is included in this paper.

Because of highly special character of these investigations in this paper we confine ourselves to the enumeration of the most important solved problems.

Methods of calculation of water displacement by gas in gently and steep dipping dome shaped aquiferous structures were worked out. These methods make it possible to take into account the absence or presence of a gas cap at the beginning of injection as well as the unloading effect at the elastic drive of an aquifer.

Special investigations were devoted to non-steady liquid and gas inflow to hydrodynamically imperfect wells. A theory was developed and a corresponding practical method of determination of geological-physical stratum parameters on the basis of data of hydrodynamically imperfect wells testing was given.

An original solution of the problem of non-steady liquid or gas filtration under the harmonic law of pressure or flow change was found. On the basis of this solution simple working formulas were obtained and a method of determination of geological-physical parameters of the collector according to pressure distribution in the stratum, caused by the influence of the change in liquid flow or pressure, was worked out.

Experimental investigations with the model of coefficient of water displacement by gas in sand weze carried out.

It was found that the displacement coefficient greatly depends on the frontal displacement velocity, sharply decreasing as this velocity increases.

Visual observations showed that there was no plug displacement of water by gas and that »blocked up» water saturated zones formed. The overburden zone of the reservoir was filled by gas faster than the bottom zone. The efficiency of displacement depends on the geometrical position of the gas injection region with respect to the unloading region. The more the distance between the injection region and the unloading region, the higher the efficiency of water displacement by gas is.

These investigations are only at their beginning, their results must be checked in practice. Finding of the conditions of the maximum displacement in a stratum which is practically always heterogeneous is the main problem.

The developed theoretical principles and working formulas found a use in strata hydroexploration, in design and carrying out experimental gas and air injection.

V SOME RESULTS OF EXPERIMENTAL WORK

The most interesting results were obtained by gas injection in one of the experimental storages. Gas was injected in a Gdov Cambrian water-bearing sandstone. Its thickness was 10—12 m.; porosity 0.22, permeability from 0.5 to 2.1 darcy, the depth of lying 800—930 m., pressure in the upper part of the structure 82 atm. The stratum was overlaid with a clay series having the thickness up to 100 m. However a lens of breccia of crystalline rocks lies in this series. This lens probably contacts in upthrust with the Gdov sandstone. Structurally the stratum is gently folded, the northern wing complicated and separated by tectonic ruptures.

The complexity of this structure caused a great volume of exploratory work. It was necessary to drill 40 exploratory wells which were further used for gas injection, unloading and observations.

Gas injection is effected by means of two compressors having the power of 1000 h.p. ensuring two-stage compression from 25 to 55 atm. and from 55 to 125 atm. and the output of 500 thousand cu.m. per day.

In 1959 for three months 23 million cu.m. of gas were injected. Injection was effected through 2—4 wells, the maximum well head pressure being 103 atm.

Injection showed good well injectability up to 500 thousand cu.m. per day, practical isolation of the northern wing of the fold and connection of the Gdov sandstone with the breccia lens. During the winter observation of pressure redistribution was maintained. Attemps at getting dry gas failed.

Since April 1960 gas injection was resumed. The maximum injection amounted to 620 thousand cu.m. per day. The well head pressure amounted to 100—102 atm. The total injection was 80 million cu.m.

At injection unloading was effected — water was let out from the wells situated down dip from the group of injection wells. Three unloading wells were situated at the distance of 700—1000 m. from the injection wells and five — at the distance of 1500—2500 m. On the whole 176 thousand cu.m. of water was let out. There was no gas breakthrough to the unloading wells. The unloading ensured more uniform and more complete water displacement from the Gdov sandstone.

To control the possible gas leakage from the breccia lens wells were drilled to the overlying sand stratum. Observation showed the absence of reaction in these wells.

In winter months an experimental gas ejection from the Gdov sandstone will be carried out.

On another area an experimental air injection into a gently dipping aquifer was carried out. Its thickness is 10—15 m., porosity — 0.20—0.25, average permeability 1.3 darcy, the depth of lying — 395—420 m., bottom pressure — 36 atm.

A group of seven wells was drilled for experiment, the injection well being in the centre, the control and observation wells being at mutually perpendicular directions at the distance of 25 and 50 m. Observations were also carried out in exploratory wells drilled earlier and located at various distances.

3260 thousand cu.m. of air under the well head pressure of injection well 40—40.5 atm. were injected, 80 thousand cu.m. per day on the average.

After pressure drop to 36.7 atm. air outlet from the same well was begun. Altogether 1423 thousand cu.m. or 44 % of injected air were let out, including 917 thousand cu.m. or 29 % of dry air, then water appeared, the quantity of which gradually increased.

Despite the relatively small scale of the experiment its results demonstrate a practical possibility of construction, under certain conditions of a gas storage in gently dipping or horizontal strata.

It is intended to continue the test, injecting a greater volume of air and making a longer delay.

Careful observations showed a very uneven air advancement in the stratum.

Average displacement radius being 300 m., some »breakthroughs» reached 1000 m.

Air displaced water only in the lower part of the stratum amounting to about one third of its thickness.

This is undoubtedly connected with the heterogeneity of the stratum and the change of its reservoir properties on the strike and cross-section. At the same time one can assume that, the volume of the injected air and injection pressure increased, the unevenness of displacement will be partially levelled off.

In 1958 and 1959 in some regions of the USSR several small underground gas storages in partially depleted gas fields were constructed.

At present four storages are in operation. For the whole period of their operation 93.1 million cu.m. of gas were injected into these storages including 53.7 million cu.m. in 1960 and 18.7 million cu.m. were withdrawn.

One storage was constructed in a Permian sand stratum lying at the depth of 400. These deposits present a small brachyanticline fold with an amplitude of 32 m.

The initial gas reserves were 30 million cu.m., the initial stratum pressure was 54.2 atm. abs. For the time of operation 18.4 million cu.m. were withdrawn, the stratum pressure decreased to 16.5 atm. abs. Injection was begun in 1958 and since that time two complete cycles of injection and withdrawal were carried out. Now the third injection is going on. On the whole 16.1 million cu.m. were injected, 10.7 million cu.m. were withdrawn. The pressure in the stratum rose to 32.6 atm. abs. and fell to 16.2 atm. abs. Injection and withdrawal were carried out by means of four wells. At the beginning of 1960 a leakage in one of the wells drilled earlier was found. At present the well is under repair.

In another region a partially depleted deposit of the field is used as an underground gas storage for 3 years, and in 1960 gas injection into other deposits of the same field was begun. By September this year 90 million cu.m. of gas were injected into all the three deposits.

The operation of storages constructed in partially depleted deposits does not cause special difficulties. From the economic point of view the use of such storages for the accumulation of summer surpluses of gas produced together with oil is the most expedient way.

In spite of the technical complexity of the construction of underground gas storages in aquifers, the economic efficiency of meeting variations in gas consumption by means of underground storages, under the condition of distant transport, is beyond doubt. It is necessary to accumulate the facts to define more exactly the quantitative criteria of efficiency under various conditions.

In the whole world there are very few underground gas storages constructed in aquifers. The most urgent problems of the technical aspect of the underground gas storage are the following ones:

- — the further improvement of the methods of exploration;
- — the development of a method reliably determining the absence of leakage of the overburden as early as at the stage of storage exploration;
- — the ensuring of controlled and uniform displacement of water by gas from a stratum which is practically always heterogeneous;

— the development of methods of storages construction in horizontal aquifers;

The exchange of information and experience among the countries, members of the International Gas Union, will contribute to the quickest solution of these problems.

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SUMMARY

The year 1948, when the first gas main, from Saratov to Moscow, was put into service, should be considered the beginning of industrial development of the gas industry in the USSR.

At that time, commercial gas reserves were extremely limited and exploratory drilling for natural gas was carried out only on a very small scale. Gas consumption was limited to public utility services.

It was after 1956 that the gas industry began to develop rapidly, which is clear from the following data on actual and projected gas output and production, in billions of cubic metres: 1955, 10.4; 1959, 37.2; 1960 47.1; 1965, 150.

Construction of gas mains, which is highly mechanized, has been carried out on a large scale; their total length increased 3.3 times in 1959 as compared with 1955, and the pipelines are mainly of large diameter (720 to 1,020 mm).

By the end of 1959, gas was being supplied to more than 230 towns and 166 workmen's settlements. By the end of 1965, towns and workmen's settlements with a total population of more than 40 million will be supplied with gas.

Realization of such high rates of development of the gas industry is based on the availability of large reserves of natural gases in various regions and in almost all of the suitable geological formations of the USSR.

The total estimated gas reserves in the USSR are 55 to 60 trillion cubic metres.

In the USSR, development of gas and gas-condensate fields is carried out on a scientific basis.

The greatest attention is paid to the study of all the geological components of a specified province — of the field or of the storage reservoir itself and of the associated hydrodynamic phenomena.

Rational operation of the gaseous field entails the choosing of a layout and spacing for the wells, and of a progressive scheme of drilling dependent on the actual hydrodynamic characteristics of the storage reservoir.

The application of scientifically based methods for the recovery of natural gas and liquid hydrocarbons leads to a sharp diminution of the number of wells to be drilled, and, as a result, to great economy of material, capital investment and labour.

Natural gas is increasingly utilized in various branches of the national economy of the USSR.

Gas utilization has increased most of all in the chemical, metallurgical and cement industries, and, especially, in the public utility services.

Industrial and domestic utilization of gas is highly effective; it results not only in decreasing the unit cost of production, but also in improving the quality of materials such as metal, cement, etc., and in raising the productivity of industrial plant such as blast furnaces, open hearth furnaces, heat treatment furnaces, cement kilns, etc.

Domestic gas utilization has resulted in considerable economy of money and labour for heating and cooking.

Town gas distribution systems are constructed in the USSR with a view to providing adequate gas supply to industrial plants, public utilities and domestic consumers.

Various methods are used to ensure regular gas supplies at different times of the year and of the day and to establish the necessary peak-demand reserves, the most effective being the construction of underground gas storages near large centres of gas consumption.

The utilization of liquefied petroleum gases is being widely developed, and the volume of L.P.G. consumed is increasing very rapidly.

Liquefied petroleum gases are used as a raw material in the chemical industry, as a source of town gas and for distribution to settlements situated far from gas mains, as a motor transport fuel, and for agricultural machinery and other purposes. For these purposes, liquefied gases are distributed by pipelines as well as by specially designed mobile tanks and in cylinders of various designs and dimensions.

RESUME

L'année 1948, au cours de laquelle le pipeline de Saratov-Moscou a été mis en exploitation, doit être considérée comme le début du développement industriel de l'industrie du gaz en URSS.

A cette époque, les réserves commerciales étaient extrêmement limitées et les forages d'exploration pour trouver du gaz naturel étaient effectués à une échelle très réduite. La consommation de gaz se limitait aux services publics.

Après l'année 1956, l'industrie du gaz commença à se développer rapidement, ce qui ressort des chiffres ci-dessous qui montrent le développement de la production et de l'émission de gaz (en milliards de m^3) :

1955	1959	1960	1965
10.4	37.2	47.1	150

La construction des pipelines a été effectuée à une très grande échelle; leur longueur a augmenté de 3,3 fois en 1959 par rapport à 1955. On construit surtout des pipelines de grande dimension (720 à 1 020 mm) et leur pose est hautement mécanisée.

Fin 1959, le gaz était fourni à plus de 230 villes et 166 cités ouvrières. Pour la fin de 1965, des villes et des cités ouvrières totalisant une population de plus de 40 millions d'habitants seront alimentées en gaz.

La possibilité de réalisation de progrès dans l'industrie du gaz à un taux aussi élevé est basée sur la disponibilité de grandes réserves de gaz naturel dans différentes régions et réparties à peu près dans toutes les couches présentant des structures favorables dans le territoire de l'URSS.

Le total des réserves prévues en URSS est estimé à 55 ou 60 trillions de m^3.

En URSS, le développement des champs de gaz naturel et la récupération du gaz des gisements pétrolifères sont effectues d'après des bases très scientifiques.

On attache la plus grande attention à l'étude de tous les éléments géologiques d'une province déterminée, du champ ou du réservoir lui-même et des phénomènes d'écoulement.

L'exploitation rationnelle des champs de gaz comprend le choix de l'implantation des puits dans le champ lui-même, de la distance entre les puits et de l'ordre de progression du forage qui dépend des caractéristiques réelles du champ et des conditions de l'écoulement gazeux dans celui-ci.

L'emploi de méthodes basées sur des éléments scientifiques pour la récupération du gaz, des condensats et l'exploitation des champs de gaz humide, a entraîné une rapide diminution du nombre de puits à forer et, comme résultat une grande économie de matériel, de dépenses et de main d'œuvre.

Le gaz naturel est utilisé de plus en plus dans différentes branches de l'economie nationale en URSS.

L'utilisation du gaz s'est surtout développée dans les industries chimiques, métallurgiques et cimentières ainsi que dans les services publics.

L'emploi du gaz dans l'industrie et pour les besoins domestiques s'est montré hautement efficient; de son emploi résultent non seulement une diminution du coût de la production mais également une amélioration de la qualité des produits finis (métal, ciment, etc.) et une augmentation de la productivité des unités industrielles (hauts-fourneaux, fours à sole, fours de traitements thermiques, fours à ciment, etc.).

L'emploi du gaz pour les besoins domestiques a permis des économies considérables d'argent et de travail à la population dans le domaine du chauffage et de la cuisine.

Les systèmes de distribution de gaz de ville sont construits en URSS en fonction des possibilités de fournitures régulières aux installations industrielles, aux services publics et aux consommateurs domestiques.

Pour régulariser la fourniture de gaz pendant les différentes périodes de l'année et au cours d'une même journée ainsi que pour assurer les réserves nécessaires, on emploie différentes méthodes.

La plus efficace est celle de la construction de réservoirs de stockage souterrain près des grands centres de consommation.

L'emploi des gaz de pétrole liquéfiés s'est largement développé et la consommation des G.P.L. augmente très rapidement.

Les gaz de pétrole liquéfiés sont utilisés comme matière première dans l'industrie chimique, pour l'alimentation en gaz des villes et des cités situées à une trop grande distance des canalisations de gaz, comme carburant pour les automobiles et les moteurs des tracteurs et des machines agricoles ainsi qu'à d'autres fins.

Les gaz de pétrole liquéfiés sont transportés par canalisations aussi bien que par camions et en bouteiles de différents modèles et de différentes dimensions.

THE PROGRESS OF GAS DISTRIBUTION IN THE USSR

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DEVELOPMENT OF GAS SUPPLY IN THE USSR

I GENERAL DATA ON THE DEVELOPMENT OF GAS INDUSTRY IN THE USSR TILL 1960

Gas industry is a young branch of the national economy of the USSR. The year of 1948 when the construction of the gas main Saratov-Moscow was completed and put into practice should be considered the beginning of gas industry development in the USSR.

In 1949 the gas main Dashava — Kiev — Bryansk — Moscow was put into practice.

The prospecting of gas fields on commercial scale began after World War II.

By 1946 commercial reserves of natural gas in the USSR were small and concentrated only in the Orenburg and Saratov Regions, the Komi Autonomous Soviet Socialist Republic and in some regions of the Ukraine (the Stanislav and Lvov ones).

Under those conditions gas recovery from gas fields was limited.

The whole gas quantity was entirely used for public utility services.

Because of the ever-growing requirements for gas fuel the production of manufactured gases in the USSR was developed to some extent. Plants for producing manufactured gases out of shale in the Estonian Soviet Socialist Republic and in the Leningrad Region and out of brown coal in the Tula Region were built.

In the cities of Moscow, Leningrad and others gas for public utility services was also produced at plants of various schemes out of various raw materials (solid and liquid fuels).

Extensive development of gas industry was necessary.

The Communist Party of the Soviet Union and the Soviet Government took measures to develop this branch of industry. In 1956 it was found necessary to develop gas industry in every possible way, to intensify geological-prospecting and exploratory work to find new gas deposits, to ensure the increase of commercial gas reserves by 85—90% for 5 years, to raise the output and production of gas to 40 billion cu. m. in 1960, i.e. to increase gas production 3.9 times more than in 1955.

In connection with the resolution of the development of chemical industry a further increase of demand for gas as a raw material for chemical and oil-chemical industry manifested itself.

In 1959 planned figures of the development of the national economy of the USSR for 1959—1965 were approved.

The planned figures envisage "... a change of fuel balance structure by means of priority development of the output and production of the most economic kinds of fuel- oil and gas. In 1965 to ensure oil output of 230—240 m.m.t, gas output and production of 150 billion cu.m.".

These plans are being successfully fulfilled. In 1959 gas output and production amounted to 37.2 billion cu.m., i.e. 3.5 times more than in 1955. In 1960 gas output and production amounted to 47.1 billion cu.m. which exceeded those of the entire year of 1957 as well as the level of the task established for 1960 by the planned figures approved according to the Sixth Five-Year Plan.

Such high rates of the increase of oil and gas output will make it possible to raise their share in the total volume of fuel production from 21% in 1958 up to 51% in 1965; the share of gas will be increased from 5.4% up to 17.5%.

Still more significant changes will take place in the structure of the fuel balance as regards the power use of fuel. The share of oil in this balance will increase for 7 years from 10.9% up to 17.8% and the share of gas will increase from 2.6% up to 24.8%, i.e. gas will constitute nearly a quarter of the power fuel.

Having started the construction of a gas grid of great length the Soviet Union began to increase fast the rates of gas mains construction. For this purpose specialized organisations were created, equipped with modern building machines and mechanisms (dig-out trenchers, pipe cleaning machines, insulating and electric welding machines, pipe line layers etc.).

As a result, if in 1941 the construction of the first gas main Buguruslan—Kuibishev (150 km) took about 1.5 year, in 1959 3,843 km of gas mains were laid.

The total length of gas mains in the USSR increased by 35% for 1959 and by the end of 1959 the gas mains grid was about 80 % of the total grid increase for the preceding two years.

Parallel with the length increase of the gas mains grid the transmission capacity of gas mains considerably increased at the rates considerably above those of length increase of gas mains. This is indicative of the fuller use of gas mains transmission capacity.

In order to increase further gas mains efficiency gas turbine power plants meeting the modern requirements of distant transmission of large gas quantities are used at compressor stations and designing of powerful gas-motor compressors is being mastered.

The development of distant gas supply in the USSR is carried out on a new basis meeting the modern requirements and the technique of distant gas transportation. This development is based on the use of pipes of large diameters. At present the length of gas mains having the diameter of 720 mm and more exceeds 40% of the total length of gas mains in the USSR whereas in the USA the share of gas mains having the diameter more than 760 mm is only 1.1%.

Gas transportation per 1 km of gas mains in the USSR amounts to about 2 m.m. cu.m/year and will be as high as 4 m.m. cu.m/year in 1965 whereas in the United States of America the volume of gas transportation per 1 km of gas mains amounts to 0.8—0.9 m.m. cu.m/year.

Despite the considerable lag of the length of the operating gas mains grid in the USSR behind the length of such grid in the USA the Soviet Union does not aim at overtaking the USA in this respect. This index does not characterize any economic superiority but rather shows absence of plan and private-ownership methods of construction of gas mains grids in the USA carried out by individual companies.

Under the conditions of planned economy in the USSR gas transportation and distribution can be carried out by means of a gas mains grid of lesser length in spite of the vast territory of our country.

This will be carried out by means of construction of gas mains of higher capacity and of their more rational use and distribution in the country.

At the construction of gas mains in the Soviet Union high-efficiency mechanisms created by national industry are widely used. The process of pipe welding and control of welding joints has been automatized. Line construction methods and original highly effective methods of laying pipe lines across water obstacles and marsh-ridden districts are used.

In 1959 mechanization of labour — consuming work at gas mains construction reached a high level: in earth work — 97%; in pipe cleaning work — 98.6%; in insulation work — 95.8%; in assembly-welding work — 71.3%.

The level of mechanization of welding work at gas mains construction achieved in the USSR exceeds the level of mechanization of this work in the USA.

In the current seven-year period of 1959—1965 it is planned to construct 40 gas mains with the diameters of 720—1020 mm.

The length of individual gas mains will reach 2000 km. The program of this construction is being successfully fulfilled.

The fulfilment of the plan of gas mains construction for 1959—1965 will make it possible to create a system of gas supply for all the fifteen Union republics forming the USSR which will be an important factor of the further progress of their economy.

The consumption of natural and casing-head gas for public utility services increased during only one year — 1959 — by 48.6 % as compared with 1958.

In the USSR all expenditures on gasification of flats used by citizens are made at the expense of the state.

People pay only the cost of the gas they use.

II INCREASE OF GAS RESERVES IN THE USSR AS A BASIS OF HIGH RATES OF THE DEVELOPMENT OF GAS INDUSTRY

To ensure the fulfilment of the envisaged plans of gas output increase in the current seven-year period as well as further rapid increase of its output in the following years it is planned to ensure an outstripping increase of discovered commercial gas reserves.

The confidence in the reality of adopted plans of increasing commercial gas reserves, necessary for rapid development of gas industry, increase of the share of gas in the fuel balance of the country and supplying rapidly developing chemical industry with raw materials, is based on the results of geophysical and geological prospecting, exploratory and drilling work, carried out in recent years in the territory of the USSR.

It was found by this work that commercial accumulations of gas and gas condensate are distributed nearly along the entire cross-section of the deposits presenting the geological structure of the territory of the USSR; at the same time very large gas-bearing zones in various regions of our country were discovered.

The work done made it possible to discover new gas-bearing regions and large natural gas fields. Only for 1959 did the commercial reserves of natural gas increase by 70% as compared with the reserves which the country had possessed by the beginning of the seven-year period.

Parallel with the increase of commercial gas quantities of already known gas fields, for 1959 and the first half-year of 1960 27 new gas fields in various regions of our country were discovered.

During the recent years serious success has been achieved in the search for gas, gas-oil and oil fields in a number of regions of Siberia.

The total estimate of natural gas reserves in this region amounts to many billions of cu.m. Very favourable results have been obtained in a number of regions of Central and East Siberia.

Within the next few years the volume of geological prospecting and exploratory work for gas in the vast territoires of Siberia, as well as in the northern regions of the Soviet Union will be considerably extended.

This undoubtedly will cause discovery of large gas reserves and will make it possible to supply these distant regions of our country with cheap fuel.

The Caspian lowland is the most perspective province with respect to gas-bearing structures. This region is still very poorly investigated. Here according to preliminary data entire sedimentary complex from Devon to Tertiary deposits inclusive is an oil- and gas-bearing one.

By its geological structure the Caspian depression reminds of the basin of the Gulf of Mexico in the USA where ¾ of all the gas reserves of the USA are concentrated and more than 230 billion cu.m. of gas and up to 70 million t. of oil per annum are produced.

The favourable geographical location of the Caspian lowland situated between the principal regions of gas consumption of the European part of the USSR and the Urals makes it especially perspective and subject to intensive prospecting.

III PROBLEMS OF DEVELOPMENT OF GAS- AND GAS-CONDENSATE FIELDS IN THE USSR

Immense problems of development of natural gas and oil output inspire the scientists, engineers and workers of gas and oil industry to creative work to raise constantly the economic efficiency of all branches of gas- and oil-producing industry — geophysical and prospecting work, drilling, technique and technology of field development, well and gas field operation.

The technology of development of gas and gas-oil fields has an importance hardly to be over-estimated for increasing economic efficiency of gas- and oil-producing industry. For comparison let us point out that capital investment in the development of large gas- and gas-oil fields in some cases may exceed those in construction of the largest thermoelectric and hydroelectric power stations, large metallurgical and other plants.

The most capital-consuming structures in gas and gas-oil fields are wells. Almost in all gas and oil fields the expenditure on wells amounts to more than a half of total expenditure. Therefore a tendency arises to reduce the number of wells in the field as much as possible. But on the other hand, other things being equal, the less the number of wells, the less the current reservoir production as a whole is and in most cases the less gas or oil take-off is too. That is why a thorough and comprehensive study of the problem is necessary in order to determine the optimum production of both the deposit as a whole and individual wells, that is, to find the most advantageous system of development. This requires a deep analysis and profound knowledge of geological, physical, gas hydrodynamic and economic factors.

Rational system of development of a gas field taking into account the development of other fields must satisfy the country's gas requirements to the full at the minimum national-economic expenditure and ensuring as full gas and oil take-off of reservoirs (deposits) as possible. It goes without saying that the raising of economic efficiency of gas or gas-oil field development by means of reducing the number of wells, must be accompanied by the growth of their production, so that the total production of the deposit or the field as a whole may not diminish and gas and oil take-off may remain high. Evidently this may be achieved by means of the optimum well spacing on the area, the optimum distance between the wells fully taking into account geological, psysical and gas hydrodynamic features, by means of rational conditions of well operation and various measures intensifying the processes of development.

But all this is possible only in case each of these problems and the system of field development as a whole are worked out or, more precisely, grounded by means of really scientific methods of designing and analysis of development of gas reservoirs and fields. These scientifically-based methods of designing of rational development of gas, gas-condensate and gas-oil deposits in every individual case are based on combined use of methods of geology, geophysics, underground gas hydrodynamics and reservoir physics, branch and general economics, nuclear physics and modern electronic computing technique.

It goes without saying that the modern level of introduction of scientific achievements into the practice of development of gas, gas-condensate and gas-oil fields will be higher and higher and our theoretical knowledge will always grow only in case constant and correct analysis of the achieved is ensured and a correct estimate of our current mistakes and achievements is given.

Summing up the above, we can point out that by the system of development of gas fields we mean the control of the process of gas migration in the reservoir (deposit) to wells by means of spacing the optimum number of operating (and observation) wells, a definite order of their putting into operation and establishment of the optimum technological conditions of operation.

In the Soviet Union every gas and gas-oil field is developed on the basis of a project of technological schemes of its development. We usually call such schemes — a general scheme of development of a field or a deposit.

The project of construction of a gas or gas-oil field is included as a rule in every general scheme of field development.

Let us briefly consider the basic principles of designing the general scheme of field development and of the project of construction of the gas field.

At designing the system of development the main requirement is to get as accurate initial data as possible which would correctly reflect the actual conditions of gas (or gas-condensate or gas and oil) accumulation in the reservoir.

For a long time we have already passed on from geological-statistic methods of estimation of the process of development to more strict, scientifically-based methods of investigation of the physics and mechanics of the migration of gases and liquid (two- and three-phase systems) in porous reservoirs and to the use of the laws of gas-liquid systems filtration at projecting field development. Methods of geological investigation of gas and oil deposits as well as methods of economic analysis of various systems of development have undergone as rapid a progress.

An example can be given to confirm this. As a result of application of scientific principles of development of Tuimaza oil field in the Bashkir ASSR for the first time the method of artificial maintenance of reservoir pressure by means of edge water flood was used in a large oil field. This made it possible to increase rapidly the intensity of using wells as industrial constructions. In this field we gave up formerly used well spacing in the form of triangle every 250 m. and passed on to well spacing in the form of ring lines parallel to the internal contour of water-oil contact in accordance with the field structure. The chosen distance between the lines was 500 m. and between the wells within the lines — 400 m. Owing to such well spacing their number was reduced nearly four times. The production of wells proved to be on the level of planned one, high and steady. Flow production method of operation was principally applied which has already remained for more than 12 years. This splendid industrial experiment carried out in one of the largest oil fields of the world made it possible to make use of the obtained experience with corresponding modifications in all other gas-oil fields of the Soviet Union.

As to purely gas and gas-condensate fields, at present we do not apply artificial methods of maintenance of reservoir pressure in them but this experience made it possible to adopt a general method of designing of the system of development of these fields and their analysis in the process of development.

At present for every gas and especially gas-condensate field being developed research and design work is carried out to determine the expediency of using methods of maintenance of reservoir pressure.

The use of gas hydrodynamic methods to determine the main technological indices of the process of development by means of electric and other models is a basic feature of the scientific principles of development designs of gas, gas-condensate and gas-oil fields. Analytical "testing" of many versions of technological schemes of development for a given deposit and obtaining the main indices characterizing different versions of a scheme allow as if to make the reservoir (deposit) work under various conditions, i.e. under various depressions, numbers of wells and their spacing, various productions etc.

To work out a general technological scheme for gas or gas-condensate field development the geological data of the given geological province and of the deposit or field, physics and hydrodynamics of reservoirs as well as all the technical-economic indices, are studied in detail.

On the basis of studying the general geology and hydrogeology of the given geological province the sources of pressure in the field and hydraulic head pressure of the water drive system are determined. On the basis of the investigation of gas inflow in wells the permeability of the reservoir and bottom hole zone according to field data, pressure bearing characteristic, reservoir conditions, productivity factor, mechanical strength of the reservoir (or more precisely, that of its bottom hole zone), well production under various conditions (under constant rate of gas flow from the reservoir to a well, constant depression, constant gradient and constant recovery etc.) are determined; reservoir pressure according to the measurements of the well, gas-water contact, the activity of reservoir waters, the possibility of water coning in wells, the conditions of water condensate falling out in the well bore etc. are determined.

Taking into account the above-mentioned factors as well as general dimensions of the structure and the thickness of separate reservoirs, commercial reserves of gas and condensate are determined and when there are oil rings, oil reserves are determined.

Complete absense of leakage on the path of gas movement from the reservoir to the surface is one of the main requirements of the rational scheme of gas field development.

Gas seepage from the reservoir through leaks in the casing or in the cement ring between the casing and the well wall or through leaks in the place of contact of the cement ring with rock on the well wall is absolutely intolerable. These strict demands are caused by the necessity both to preserve gas reserves and to ensure the safety of people living and working in buildings situated in the zone of possible gas migration.

On the basis of the general scheme of field development a project of construction of the field is worked out. This project envisages: well head setting up; series-parallel gas gathering system; gathering, gas purification, dehydration and metering centres; gas gathering pattern; gathering system of pipe lines for gas condensate; water pipe lines and sewerage; power lines and lighting circuits; communication system; roads; fields offices, repair shops, garage etc.; settlements for personnel. If there is a sufficient quantity of gas condensate in the field, gas distillation facilities and plants for additional gas dehydration and purification on head constructions of gas mains are installed.

In gas-oil fields besides these installations according to the quantity of casing-head gas (recovered together with oil) gasoline plants are built, in some cases of large capacity.

In the USSR the problems of telecontrol of the principal objects of gas fields are on the whole solved. These objects include wells in operation spaced on vast field territories, the systems of gas gathering and local gas transport, gas separation, purification and dehydration as well as gas metering.

However it is necessary to point out that all work in the field of telecontrol and automation of gas production did not include the principal technological process of gas and gas condensate field development, that is the process of control and regulation of gas reservoir operation. One can imagine a reservoir of approximately uniform properties and thickness with wells spaced according to the project of field development. Development drilling of the deposit is completed, rates of development and consequently the level of gas output are determined too.

In this case the control of the process of development can be based either on the principle of uniform pressure decrease in the gas deposit or on the principle of uniform gas front advancement.

When maintaining reservoir pressure in the process of gas condensate field development gas and gas-condensate recovery from separate wells as well as distribution of gas repressuring among injection wells must be determined, also according to the principle of uniform gas front advancement.

As the operation of some wells is stopped for long terms there will be a very complicated problem of finding in the process of field development for every moment of time, the distribution of the predetermined total gas production among separate wells in operation and the total volume of water repressing through injection wells, to preserve the above-mentioned conditions as well as the permissible depression value.

The problem of the control of the processes in the reservoir characterized by its considerable heterogeneity will be very complicated too.

Automatized control of the process of development will evidently include: primary instruments supplying information about the current condition of the reservoir and apparatus treating this information and either making recommendations on the control of this process or directly controlling it by means of actuating mechanisms.

At present Soviet experts in automation of gas and oil producing industry are working out such a program of control. It is evident that in the nearest future the solution of these problems will be found by means of special electronic computers combined with electronic analogue computers.

These electronic computers and analogue computers will also find wide application for the solution of problems of complex designing, rational methods of field development, gas gathering, purification and distant gas transportation.

IV STRUCTURE OF NATURAL GAS UTILIZATION

The use of fuel and power resources of our country having the most favourable technical-economic indices and thermal characteristics is the general line of the development of fuel and power industry of the Soviet Union for the current seven-year period.

Growth of natural gas utilization in the USSR by main consumers during a three-year period is characterized by the following indices:

	Ratio of 1959 to 1957
Total growth of gas consumption	1.9 times
Growth of gas consumption by:	
a) public utility services	2.4 »
b) industry	1.9 »

Thus priority growth of gas consumption for the above-mentioned period took place with utility services and despite relatively great difficulties in the gasification of utility consumers as compared with gas supply to industrial enterprises this task is the primary one when problems of gas supply of the country are being solved.

Among industrial consumers the greatest growth took place with metallurgical, chemical and cement industry.

Natural gas supply to power stations deserves special attention. This consumer is of great importance for gas industry because it can not only utilize large quantities of gas but also diminish monthly and daily gas consumption fluctuations.

V TECHNICAL-ECONOMIC INDICES OF GAS UTILIZATION EFFICIENCY IN DIFFERENT BRANCHES OF INDUSTRY AND IN PUBLIC UTILITY SERVICES

Wide utilization of natural gas in the national economy of the country gives a great economic effect. Suffice it to point out that labour expenditure per 1 ton of natural gas production (in terms of standard heating value fuel) is about 20 times less than per 1 ton of coal production. The cost of gas production is about 8—10 times less than that of coal production.

When utilizing gas, plants efficiency increases, production quality improves and sanitary labour conditions improve radically.

One should bear in mind that the degree of efficiency which is achieved by industrial enterprises, when utilizing gas, is different; it depends on many factors, namely on the kind of fuel substituted, its cost, distance of gas transportation, process technology, type of plant units etc.

Ferrous metal industry is one of the large consumers of gas entirely for technological purposes. Gas utilization in the blast furnaces process (100—110 cu.m. of gas per 1 ton of cast iron) makes it possible to reduce coke consumption by 15% as well as to improve the process technology by means of raising blast temperature, decreasing slag share and heat losses with off-gases etc.

The efficiency of the utilization of natural gas in open-hearth furnaces is also high.

In mechanical engineering and metal-working industry a considerable effect is achieved by natural gas utilization.

Using gas instead of other kinds of fuel in various heat treatment furnaces and furnaces for punching, pressing and forging improves their efficiency, reduces fuel consumption, waste and losses from scale.

Substituting natural gas for oil fuel in various heat treatment furnaces makes it possible to raise furnace efficiency by 2—4%, to decrease fuel consumption thanks to better mixing of gas with air as well as to reduce heat losses to the surroundings and with off-gases.

Inside factory expenditure on fuel transportation and on other economic items decreases simultaneously. It should be especially noted that substitution of natural gas for other kinds of fuel in heat treatment furnaces facilitates the application of more progressive technology and design of plant units themselves which can be confirmed by the following comparison of results of calculations made.

(in % to the indices of an oil fuel furnace)

	Oil fuel furnace	Gas furnace Ordinary	Gas furnace High-speed
Efficiency	100	110	175
Standard heating value fuel consumption	100	92	59
Waste of metal	100	67	17
Cost of heating	100	92	61

In the industry of building materials natural gas is also widely used. Economic efficiency from gas utilization in this industry is considerable too.

In cement industry gas utilization makes it possible to reduce specific fuel expenditure and consequently to reduce the cost of a production unit. Besides the efficiency of cement kilns working on gas increases.

Cement quality improves, capital investments in building new plants diminish and the total quantity of service personnel is reduced.

In electric power stations substitution of gas for solid or liquid fuel greatly affects the reduction of electric power cost.

Besides, electric power plants operation on gas causes an increase in the efficiency of boiler plants.

Natural gas utilization for gas supply of towns, settlements and rural regions is of great social-economic importance.

Besides the above-mentioned branches of industry and utility consumers natural gas in the USSR is used for technological purposes in textile, light and food industries as well as in oil-gas industry (for manufacturing of special sorts of carbon black).

In all cases natural gas utilization improves technical-economic indices of production and in a number of regions this kind of fuel is preferable to others.

The highest effect is gained by natural gas utilization for technological needs of industry; gas utilization in energetics is less effective but also in this case indices are incomparably better than at utilization of solid fuels.

VI TOWN GAS DISTRIBUTION SYSTEMS

Gas supply of towns and settlements in the Soviet Union is carried out mainly on the basis of natural gas.

When designing town gas distribution systems a complex solution of all problems of gas supply of utility consumers and industrial enterprises etc. is achieved.

Socialist economic system, lack of private property of land and mineral wealth make it possible, when designing gas distribution systems, to solve problems, connected with gas transport to towns, routes of mains, placing of structures of town gas facilities and organization of their construction etc. in the most rational and economic way.

Designing of town gas distribution systems is carried out by specialized organizations which solve the problems of gas transport from a gas distribution station to town and by town gas grids to the consumer. Gas supply designs are worked out on the basis of approved general plans of town planning and building taking into account their long-term development. This makes it possible to choose the scheme of gas supply correctly and economically and to establish priorities in construction of gas pipe lines and other gas facilities.

Designing of town gas distribution systems is carried out in two stages: design plan with summary estimate-financial calculation of construction cost and working drawings with estimates defining the cost of separate structures.

In the project plan the whole complex of problems connected with the construction of gas distribution system is solved. These problems include a rational direction of gas utilization combined with other kinds of power supply (electrification and introduction of district heating plants), the choice of a type of the system suitable for the town as a whole and for its various building districts, the choice of types of facilities included by the system and their spacing in the town territory, volume and cost of work, sequence and economy of construction and operation of facilities etc.

The following systems are used for town gas distribution depending on pressure:

a) single-stage system — gas distribution and transport to consumers only by gas pipe lines of one (usually low) pressure;

b) two-stage system — gas distribution and transport to consumers by gas pipe lines of two pressures (mean and low or high and low);

c) three-stage system — gas distribution and transport to consumers by gas pipe lines of three pressures (high, mean and low);

d) multistage system — gas distribution and transport to consumers by gas pipe lines of four or more pressures.

The following values of gas pressure are permitted for town gas pipe lines by the approved technical standards:

a) low pressure gas pipe lines — up to 300 mm. WC or up to 500 mm. WC on condition that a local pressure regulator is installed on every inlet to a building, flat etc.;

b) mean pressure gas pipe lines — above 0.05 kg/cm^2 and up to 3.0 kg/cm^2;

c) high pressure gas pipe lines — above 3.0 kg/cm^2 and up to 6.0 kg/cm^2;

d) high pressure gas pipe lines — above 6.0 kg/cm^2 and up to 12 kg/cm^2;

e) gas pipe lines of higher pressures — on condition of their necessity and in accordance with a permission of the technical supervision in every individual case.

Gas is supplied to dwelling houses, public buildings, municipal service buildings and industrial enterprises from town distribution gas pipe lines of low, mean and high pressure (up to 6.0 kg/cm^2 inclusive). Gasholder stations, town gas regulation stations and industrial enterprises requiring high pressure gas (gas turbine power plants, chemical and metallurgical plants and plant units equipped with high pressure burners etc.) are connected with town gas pipe lines with pressure above 6.0 kg/cm^2 and up to 12 kg/cm^2.

Gas pipe lines of different pressures are connected only by means of gas regulation stations equipped with pressure regulators and safety devices preventing pressure increase beyond permissible value.

The choice of gas distribution system and its pressure is determined by the project depending on the area and planning of the town, gas supply sources, physical and chemical gas parameters, volume of gas consumption, location of municipal services and industrial enterprises to be supplied and gas-holders. This choice is based on corresponding technical-economic calculations.

When designing town gas grids one provides for reliability and regularity of town gas supply, safe operation, easy and simple service, possibility of cutting-off separate town districts or microdistricts, possibility of construction and putting in operation by stages, uniformity of structures and assembly units, minimum material and capital investments and operating costs.

Town gas distribution system is calculated for maximum hour consumption determined by means of the combined maximum daily schedule of gas consumption by all kinds of consumers.

Hydraulic calculations of low pressure town gas pipe lines as well as branches and inlets are made to provide for operation of domestic gas apparatuses in the range between nominal and maximum heat loads.

It is assumed that the maximum heat load of domestic gas apparatuses cannot exceed the nominal one more than by 20%, and decrease of heat load with regard to nominal value can be permitted only for a short term and cannot exceed 20% either.

Hydraulic calculations of mean and high pressure town gas pipe lines, branches and inlets are made to provide for reliable operation of town and industrial gas regulation stations as well as burners of utility services and industrial enterprises within the required range of heat load changes.

Town gas pipe lines, irrespective of their purpose and the pressure of transported gas are laid at the depth not less than 0.9 m. from ground surface to the top of the pipe.

Crossings of rivers, canals and other water obstacles are made underwater. When crossing rivers with unstable channel and banks, with high velocity flow (above 2 m/sec), arched crossings, as well as crossings by suspension and specially constructed bridges are used.

In individual cases open layout or suspension of gas pipe lines (with gas pressure up to 3 kg/cm^2) to reliable constructions of existing metal and reinforced concrete motor highway bridges and footbridges are used too.

In the USSR only steel pipes are used for town gas pipe lines. At present research institutes are investigating the problems of using non-metallic pipes.

The construction of town gas pipe lines is carried out by specialized organizations.

The technical supervision of the quality of construction and assembly work is carried out by a town gas board which is established as soon as the construction of town gas distribution system begins. The same board examines the objects whose construction is finished and later on runs them.

The large share of industry in gas consumption in the towns of the USSR makes it comparatively easy to level off daily fluctuations of gas consumption by domestic and utility consumers.

When designing town gas supply with natural gas, construction of gas-holder stations is not planned as a rule.

It is more difficult to level off weekly fluctuations because on Sundays gas consumption by industrial enterprises and power stations sharply decreases. At present in the towns of the USSR the regulation of week fluctuations is carried out by means of a number of methods depending on local conditions.

When towns are supplied with natural gas and are situated near gas fields, gas transport is done according to a schedule corresponding to daily and weekly working conditions of gas consumption.

When towns are situated far from fields, weekly fluctuations are levelled off using the accumulating capacity of gas mains (final section of gas main).

In individual cases levelling off is carried out by means of alternating gas supply to large industrial boiler houses or power stations equipped with combined gas-oil fuel or gas-coal dust burners.

Levelling off considerable monthly fluctuations of gas consumption during the year presents a very complicated problem for town gas system. At present the most widespread method of seasonal regulation of town gas consumption is the method of gas supply to large gas consumers for levelling off gas consumption for 5—8 months a year.

The rest of time these enterprises work on solid or liquid fuel.

A number of drawbacks of this method of seasonal regulation make it necessary in some towns to construct special installations for regasification of L.P.G. (propane and butane) using them for peak shaving in winter time.

However even these measures of levelling off seasonal fluctuations of gas consumption in towns cannot solve completely the problems of seasonal regulation.

For this purpose at present in the USSR preparations are made to construct underground gas storages near large industrial centres.

The method of accumulation of summer gas surpluses in underground storages and utilization of these surpluses in winter period makes it possible to solve better the problem of levelling off the seasonal fluctuations of gas consumption by town consumers.

The economy of construction of town gas distribution systems varies within wide ranges. This is accounted for by the variety of town planning and building, of the structure of gas consumption, i.e. the share of industrial gas load, of engineering geological conditions of gas pipe line laying etc.

In towns with a large share of industrial gas load and dense spacing of industrial enterprises specific metal and capital investments are considerably less than those in towns with a small share of industrial gas load and sparseness of enterprises throughout the town area.

The systems of gas distribution for towns with dense multistory building have more economic technical-economic indices. For towns with sparse few-storeyed building these indices are worse.

VII GAS SUPPLY ON THE BASIS OF LIQUEFIED GASES

In recent years liquefied petroleum gases (propane, normal butane, izo-butane, propylene, butylene and their mixtures) obtained in processing casing-head gases at gasoline plants, in oil processing and stabilization of oil and gas condensate in fields acquire an ever-growing importance for gas supply of the country.

Rapid development of oil and gas industry as well as the fact that there is a wide field for using these gases favour wider utilization of L.P.G. These gases can be used as raw materials for chemical industry, fuel of high calorific value for public utility services, as motor fuel for internal combustion engines (transport and stationary ones), as power and technological fuel in various branches of industry, in agriculture, for metal cutting and in other branches of national economy and domestic use.

In pre-revolutionary Russia there was no processing of casing-head oil gas. In 1924 in the town of Grozny the first gasoline plant was put into operation.

At present the construction of gasoline plants has considerably gained in scope. Gasoline plants have been constructed in the fields of Bashkiria, Tataria, Kuibishev Region, Azerbaijan and the Ukraine.

The seven-year plan of development of national economy of the country envisages a vast program of further construction of such plants. It is planned to construct both powerful stationary plants for processing hundreds of millions of cubic metres of gas a year and small mobile units of low capacity for processing up to several millions of cubic metres of gas a year.

These plants and units are completely automatized and provide for high recovery of gas fractions including such gases as propane and ethane.

As a result of realization of planned construction of plants and units, the volume of gas processing will increase in 1965 by 4 times as compared with 1960.

At present in the USSR it is necessary to improve technological schemes of liquefied gases recovery to increase gas recovery of the final products in connection with rapid development of chemical industry requiring large quantities of liquefied gases and with considerable growth of liquefied gases consumption for domestic purposes and for motor transport.

New technological processes with application of cold (low-temperature separation) are being developed and used in new-constructed plants.

Continuous method of hydrocarbons recovery by means of activated carbon permitting to recover all propane and 60—70% of ethane is being mastered. Besides it is also planned to reconstruct the operating gasoline plants.

Taking into account the rapidly growing demand of the national economy of the USSR for liquefied gases high rates of their production growth are planned providing for an increase of production in 1965 by 38 times as compared with 1958.

Liquefied gases are transported by special tank cars or by pipe lines. This latter means of transport is growing more and more. A design of a tanker for liquefied gases transportation by water is developed.

Liquefied gases utilization by utility and domestic consumers is developing faster than by other consumers. Liquefied gases consumption for utility and domestic use will increase in 1965 by 30 times as compared with 1958.

There will be priority development of the group system of gas supply of flats. The share of this system in the total volume will increase from 10% in 1960 to 35% in 1965.

The construction of a great number of group storages for L.P.G. to supply rural regions with liquefied gases began in the Moscow Region, Byelorussia, Kasakhstan and its virgin lands, in the Altai territory and in some other regions.

To provide for liquefied gases transportation to utility and domestic consumers mass production of cylinders and tank trucks has been organized.

A design of tank trucks having the capacity from 4 to 14.5 cu.m. has been worked out and their production has been organized.

The produced cylinders for liquefied gases transportation have the capacity from 1 to 112 litres.

A system of L.P.G. distribution centres for packing up and retail trade of liquefied gases is being created.

L.P.G. distribution centres and group storages being constructed have various capacity — from 3 thousand to 100 thousand tons a year. In every case the centre capacity is chosen depending on the local consumers.

In the USSR work is carried out on construction of liquefied gases underground storages in various geological structures (in salt domes, clays, exhausted oil and gas reservoirs).

The construction of such storages will make it possible to solve problems of levelling off seasonal fluctuations of liquefied gas consumption, to satisfy better the increased demand of domestic consumers during the cold period of the year, as well as to organize more regular railway transportation of liquefied gases.

Liquefied gases conversion of motor transport is of great importance for the national economy.

In the nearest future it is planned to convert to L.P.G. a great number of motor cars in Moscow, Leningrad, Sverdlovsk, Kuibishev and many other cities. Besides improving technical-economic indices this will clear the air of the cities from exhaust gases.

Liquefied gases exceed high grades of gasolines in many indices, namely:

	Maximum compression ratio	Octane number
Propane	8 —12	112
n-Butane	7 — 8.5	94
i-Butane	7 — 9	103
Ethylated gasoline	6.5— 7.5	91

This makes it possible to raise compression ratio of the engine and correspondingly to increase its power. An increased compression ratio diminishes specific fuel consumption per power unit, therefore new-constructed engines or engines modernized for operation on L.P.G. have higher economic indices of operation than gasoline engines. Besides, engine operation on L.P.G. makes it possible to decrease the consumption of lubricating oils and to increase the engine run between repairs by 100—150%.

Liquefied gases are utilized more and more widely in rural regions not only as domestic and utility fuel but also as motor fuel for the engines of agricultural machines.

* * *

The work on increasing gas reserves, improving the methods of prospecting, development and operation of gas and gas-condensate fields and wells, building of gasoline plants, construction of wide gas mains network, increasing the production of facilities for liquefied gases transportation, carried on in the USSR, makes it possible to solve successfully the problem of gas supply not only of large industrial centres, towns and workmen's settlements, but also of a considerable part of rural regions of the USSR and thus to contribute to the further flowering of our great Motherland.

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SUMMARY

The construction of gas pipelines in the USSR is expanding year by year. They are built all over the vast territory, in different geographic and climatic environments, and there is a trend towards further increase in their length and size.

Standards and specifications regulating pipeline construction are systematically revised to keep them abreast of current developments in construction technique. Pipeline design has been modified to make tensile rather than yield strength of steel the main criterion of pipe quality. The physical characteristics of pipes have been improved, resulting in a saving of metal.

Gas pipelines in the USSR are built by specialized contractors working under the guidance of the State Gas Industry Department »GLAVGAS», and involve assembly line production methods. The various operations involved in laying a pipeline are highly mechanized.

Clearing and grading of rights-of-way are accomplished by means of specialized equipment. During the winter construction season, at sub-zero temperatures, special techniques and machinery are used.

The field welding of pipelines is accomplished by automatic machines employing the submerged-arc or CO_2-shielded arc technique. To cut down welding over ditches, pipes are triple-jointed on semi-stationary yards. The quality of welds is controlled by magnetographic flaw detectors or by gamma-ray radiography.

Pipelines are coated mainly with asphalt-based enamels, and, not long since, self-adhesive plastic-tapes became available. Extensive experiments are made in mill coating pipes with silicate enamels and plastics. Coating is supplemented by cathodic protection and electric drainage.

Rivers, railroads and highways are crossed by carrying pipelines underground, or underwater, or by aerial suspension.

Compressor station buildings are constructed of prefabricated frame and cladding sections. Thanks to standardization of constructional sections, and of whole buildings, the general layout of compressor stations has been improved and the number of station buildings lessened. Extensive panels having aluminum-alloy frames covered with asbestos-cement sheets and stuffed with mineral wool are used as wall sections.

Increases in the scale of pipeline construction call for uninterrupted progress of engineering techniques. To this end, scientific, planning and constructional organizations are working on a great number of technical, managerial and economic problems in striving for improvements in the quality of steels, in methods of pipeline welding and the prevention of corrosion for new and better designs and building techniques, with the ultimate objective of raising the level of mechanization of pipeline construction and reducing the cost thereof.

TECHNIQUE OF GAS LINE AND COMPRESSOR STATION CONSTRUCTION IN THE U.S.S.R.

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I INTRODUCTION

Natural gas production and consumption greatly rose in importance for the U.S.S.R. national economy during the last few years. Only three years ago in 1958 natural gas production did not exceed 30 milliard cubic meters. In 1965 its production will amount to 150 milliard cubic meters. Intensive growth of the natural gas industry predetermined the steady expansion of the gas transmission lines construction. More than 26 000 km of gaslines will be built in 1959—1965, their total network will rise to 35 000 km.

Gas transmission lines construction was started soon after the end of the World War II. No later than in 1947 840 km long, 325 mm diameter Saratov — Moscow gas line was put in service. Since then there was built a number of pipelines extending from gas fields in the Ukraine, Volga area, Stavropol region, Bashkiria and other parts of the country. In 1951 1 300 km, 529 mm Dashava-Kiev-Moscow gas line was completed, and in 1958 — 1 300 km Stavropol—Moscow gas line made up of two parallel lines 720 mm and 820 mm in size.

In 1959—1960 there were put into service such gas lines as Serpukhov—Leningrad, 813 km long and Karadag—Tbilisi, 510 km long (both — of 720 mm diameter); Dashava—Minsk, 622 km long and Krasnodar—Serpukhov, 637 km long (both — of 820 mm diameter); Shebelinka—Ostrogozhsk, 246 km long, 1 020 mm in size. A number of other gas lines are under construction at present.

Seven-year national economic plan of the U.S.S.R. calls for the construction of two parallel 2 160 km, 1 020 mm gas lines from gas field Gazli, Uzbekistan to Chelyabinsk and Svedrlovsk, Ural. In addition Sverdlovsk will receive gas from newly discovered Berezovo gas field in West Siberia.

There will be built a new gas line in East Siberia too, from Ustj—Vilujskoje to Yakutsk. The Kerch strait connecting Black and Azov seas will be crossed by the subwater pipeline destined for transmission of gas from Kuban fields to Crimea.

A branchy network of transmission gas lines (fig. 1) will connect all the Union republics of the country. Construction is to be carried in different geographic regions with diverse climatic conditions, including deserts of Central Asia, mountains of the Ural and the Caucasus, peat-bogs of Byelorussia and the Baltic Republics, Siberian taiga with its eternal congelation, and so on.

Pipeline construction is characterized by continuous shift of working site and by great saturation with machines and equipment.

Gas lines construction impending will differ from that in previous years not only quantitatively but qualitatively too. The lengths of pipelines and their diameters are increasing year by year. It may be worth mentioning that by 1960, 300 mm gas lines constituted only 18 per cent of total mileage, 529 mm — 23 per cent, 720 mm — 27 per cent, and gas lines of larger than 720 mm diameter — about 38 per cent. Volume of gas transported via pipelines taken in relation to one kilometer of their length amounts in the U.S.A. to 990 000 cubic meters. In the U.S.S.R. it is already 2 080 000 cubic meters and by the end of 1965 it will exceed 4 200 000 cubic meters.

Construction of larger diameter pipelines is economically very advantageous. If to take the cost of construction and operation of 300 mm diameter pipeline for unity, index for 500 mm pipeline will be 0.46, for 700 mm — 0.29, for 800 mm — 0.23 and for 1 020 mm pipeline — only 0.17. It is intended to commence by 1965 the construction of 1 220 mm gas lines.

II DESIGN OF PIPELINES

From time to time Codes for gas transmission and distribution piping systems governing their design and construction are revised to keep them abreast of current developments in engineering and fabrication techniques. In 1960 a new draft of the Code was prepared with a special attention to the problems of strength and safety and that of determination of the optimal diameter. As the long distance gas lines construction requires big quantities of steel its sparing becomes especially important.

This draft envisages a substantial change of the pipeline design procedure officially approved five years ago was substancially changed. According to the original rules pipelines were designed proceeding from the carrying capacity of pipes determined by the yield strength. As the yield strength was made the main criterion of pipes quality it was very naturale that the pipe industry aimed at raising yield strength by all technically conceivable means first of all by cold expansion. As was clearly shown by theoretical research and experimental studies cold expansion not contributing to raising of pipes carrying capacity in effect led to deterioration of their plasticity and ductility. It was shown that actual be-

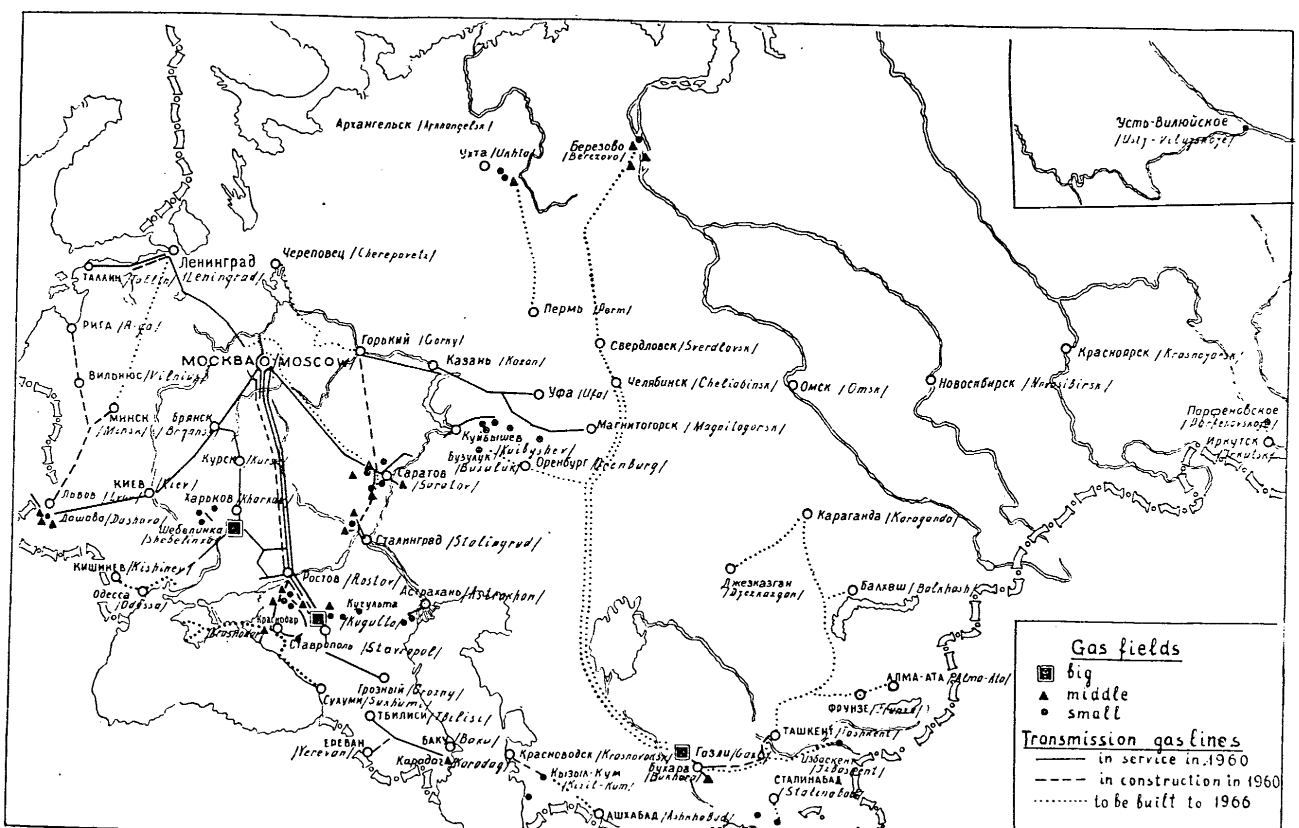

Fig. 1. Gas transmission lines in the U.S.S.R.

haviour of piping is determined by tensile rather than yield strength of steel. Accordingly new rules prescribe to design pipelines proceeding from tensile strength of metal and recommend to keep the cold expansion factor as low as possible.

Gas transmission lines nowadays work at a pressure of 55 atm (gauge).

Now pipes are made of low-alloyed steels having the minimal tensile strength of 48 kg/mm². In 1960 50 kg/mm² tensile strength steels became available, and the production of steels with tensile strength as high as 60 kg/mm² will be started in 1962. Steel industry is studying the possibilities of the production of steels with even higher tensile properties.

Steels earmarked for welded pipes fabrication are to meet specifications as to plasticity and ductility. The prescribed yield strength to tensile strength ratio for the sheet metal is minimum 0.65 and for the finished pipe — maximum 0.85.

Pipes are produced with wall thicknesses amounting to 0.011—0.015 of their outside diameter. Construction experience indicates the possibility of immediate use of pipes with wall thicknesses equal to 0.01 OD.

In compliance with the new code pipe wall thickness required is to be computed from the following formula:

$$t = \frac{P\,D_o}{2\left(\frac{S_t}{A} + P\right)}$$

where

t = pipe wall thickness, cm
D_o = outside pipe diameter, cm
P = working pressure, kg/cm²
S_t = tensile strength of steel in sheet, kg/cm²
A = safety factor for the carrying capacity equal to $\frac{n}{mk}$

where

n = factor of possible overloading of pipeline, assumed to be 1.15
m = factor making up for possible deviation of the actual working conditions of the pipeline from those assumed in the design. For the under- and aboveground pipelines this factor is taken for 0.9, for the pipeline crossings — for 0.75.
k = factor characterizing homogeneity of metal in finished pipes, assumed to be 0.65.

Pipe wall thicknesses equal to 0.01 D_o correspond to $S_t = 98\ P$. Accordingly, steels required for pressures of 55 and 65 atm (gauge) are to have tensile strength of 54 and 64 kg/mm².

Capacities of the gas lines in correlation to working pressure, compressor stations spacing and ratios of gas pressures at the inlet and outlet of the compressors are shown graphically on fig. 2. These curves describe also the unit expenditure of steels with different tensile properties for one kilometer of gas lines of different diameters and for 1 000 000 cubic meter of gas transmitted.

As on the one hand expenditure of steel of given strength for a unit length of pipeline and for a unit of its capacity practically does not change with pressure, and, on the other hand gas carrying capacity of a pipeline is advantageously regulated by the line diameter there are no grounds for the further considerable raise of working pressure. As to the required steel strength it is directly related to the designed working pressure.

In contradistinction to the world practice Soviet standards do not prescribe the corrosion allowance in computing the pipe wall thicknesses required and indeed prohibit such an allowance. It is considered irrational to protect metal with metal itself. Adequate protection of buried pipelines is to be secured by anticorrosion coatings and cathodic installations.

In foreign practice one of the principal criteria determining the pipe wall thickness and test pressure is population density index for the territories crossed by a pipeline. Soviet standards regard the high pressure gas lines explosion-liable structures which failure endangers humain lives. This is why the Soviet standards ban laying such gas lines within cities, towns and other settlements. These standards prescribe minimum allowable distance from gas line to different buildings and structures and areas of possible congestion of the people.

New standards recommend wider application of the aboveground laying of gas lines, and aerial river crossings. Typified engineering solutions, unified component assemblies, prefabricated elements of modern effective materials for compressor station buildings etc. are being used more often than ever.

III MANAGEMENT OF GAS LINES' CONSTRUCTION

Construction of gas lines is controlled by the State Gas Industry Departement »GLAVGAS» which commands big design and engineering bureaus carrying out the route surveys and complete engineering design of gas lines. Construction of pipelines, crossings and compressor stations is done by contractors specializing in definite operations.

Organizations carrying out cleaning, coating, wrapping and laying down operations, and constructing the compressor station buildings have responsibilities of the general contractor.

Specialized organizations in charge of the clearing and grading the right-of-way, digging the ditch, welding the pipeline, construction of the difficult subwater crossings, erection of the compressor station equipment and installation of the communications are subordinated to the general comtractor as sub-contractors.

All the complex of the works on the right-of-way is made on the mass line production principle. First of all on the right-of-way appear mechanized spreads doing all the preparatory work including right-of-way clearing and grading and constructing temporary roads and approaches. The same spreads dig and backfill the ditch after laying-in the pipe. Spreads coming next string the pipe along the ditch and weld them into strings. They are followed by the mechanized spreads, cleaning, coating, wrapping pipe and laying it down into the ditch.

Major river underwater crossings are constructed by special »Administration for subwater construction», having at its disposal dredgers, jetting machines, diving and other equipment.

Works and factories manufacturing pipeline valves, fittings and their ready-to-field erection assemblies are controlled by the »Industrial Supply Administration».

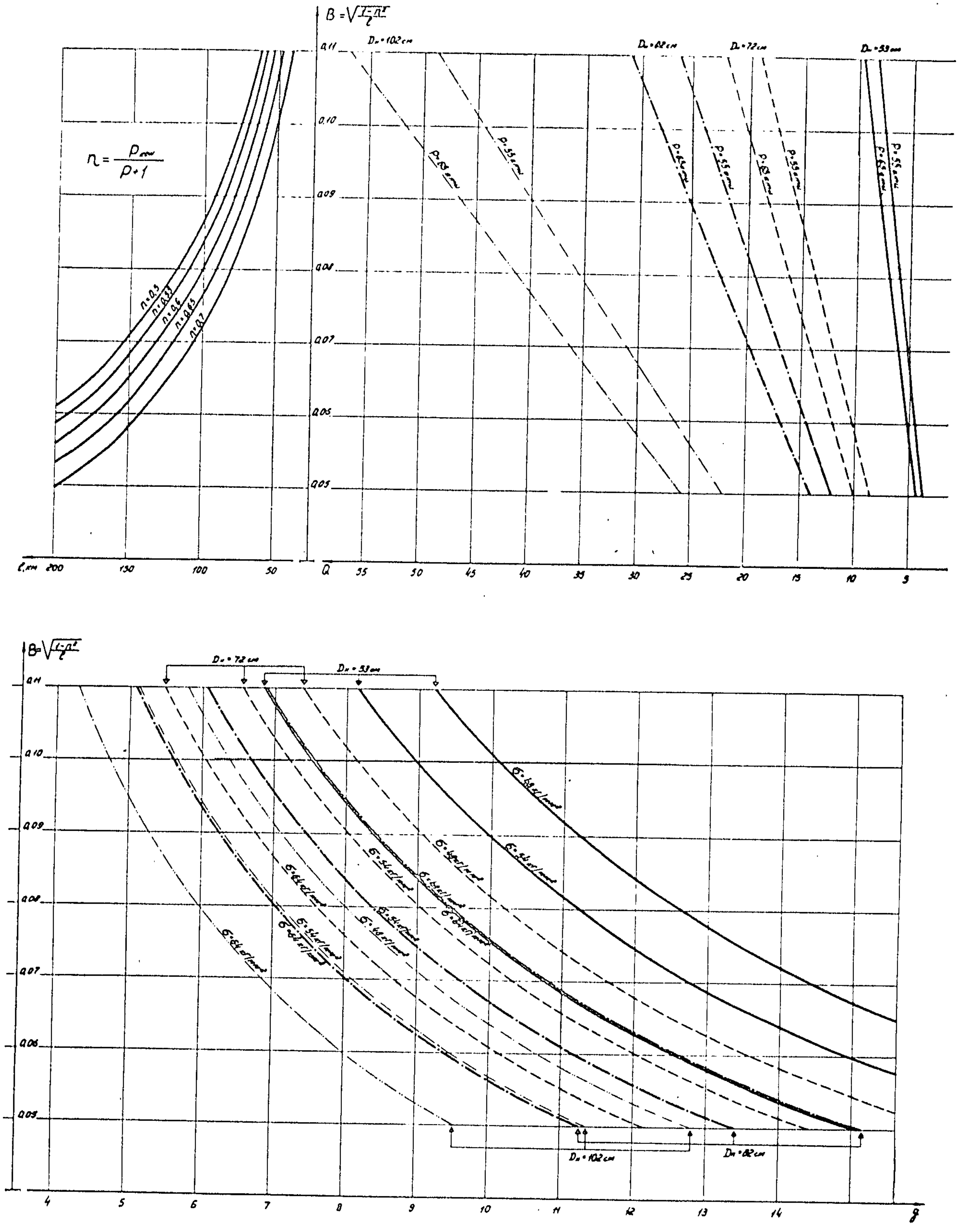

Fig. 2. Capacities of gas lines of different diameters and steel expenditure for their construction
Q — *daily gas line capacity, mln. m³*
g — *unit expenditure of steel of different strength for 1 km of length and 1,000,000 m³ of capacity of a gas line*
l — *interval between compressor stations, km*

Specialization of the building contractors corresponds to mass line production principle and adding to the mobility of contractors helps to speed up the deployment of construction in new regions. At the same time it faciltitates raising qualified cadres of workers, technicians and engineers, and creates the conditions necessary for better use of equipment.

Thanks to the saturation of the spreads by the specialized equipment, level of mechanization of the different operations achieved in 1959: in digging — 97,8 per cent, in pipe cleaning — 98 per cent, in pipe coating — 95,8 per cent, and in welding — 74 per cent. Total horsepower of equipment and machinery falling on each worker employed in the pipeline construction in 1960 exceeded 25.

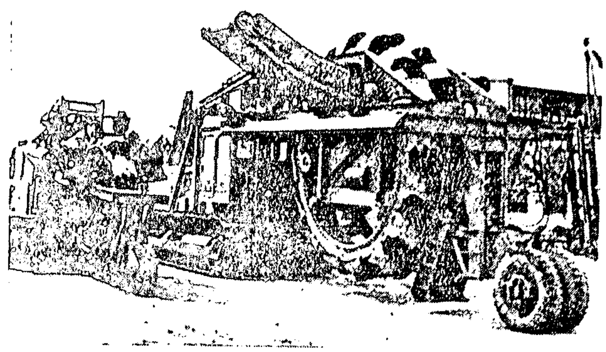

Fig. 4. Universal diesel-electric wheel ditcher

IV RIGHT-of-WAY PREPARATION AND EXCAVATION

Cycle of preparatory works on the right-of-way includes clearing the pipeline route from trees and stumps, grading, and making approaches to site of construction and temporary roads within it.

Right-of-ways clearing is accomplished by tractors, bulldozers, bush-cutters and other equipment. Preliminary grading of the right-of-way is to secure smoothness of its relief. To facilitate trafic of trucks and construction equipment along the right of way the slopes are graded and the ravines filled up, and obstacles by-passed by specially done roads. Right-of-way grading is accomplished usually by a column of bull-dozers and other related machinery.

Fig. 3. Wheel ditcher »ER-5»

Pipeline trenches are usually dug by wheel ditchers (fig. 3). Dimensions of the trenches dug with ditchers of different design are as follows.

Trench dimensions, m	Type of the wheel ditcher				
	ER-4	ER-5	ER-5A	ER-7A	ER-10
Depth	1,80	2,20	2,00	1,80	2,50
Width	1,10	1,20	1,45	1,20	1,50

Fig. 4 shows the universal diesel-electric wheel ditcher capable to dig trenches 1.2—2.5 m wide without changing the width of the working machine. This ditcher successfully excavated trenches in grounds frozen to a depth of 1 meter and in the friable rock.

For digging trenches at the bends of the right-of-way with radius less than 50 m, in the boulder clay, in woodlands, in quicksands and in high ground water terrain use is made of backhoe diggers having the following characteristics.

Diggers characteristics	Type f the backhoe digger			
	E-352	E-625	E-653	CT-202
Dipper capacity, m^3	0,35	0,65	1,65	0,50
Unit groun pressure, kg/cm^2	0,20	0,65	0 20	0,74

In rock terrain ditches are made by ripping to as great a depth as practical or by blasting. Sometimes blasting technique is used for digging frozen grounds too.

After lowering down the pipe the trench is backfilled by bulldozers and special backfillers which make the initial fill with sifted rock free material.

In winter pipeline construction the interval between the consequent operations of digging the ditch, cleaning, coating and lowering-in the pipe and backfilling is kept as short as possible, preventing thus freezing excavated ground together and deterioration of the coating due to sub-zero temperature influence. Ditching in the ground frozen to a depth of 0.5—0.9 m is made with wheel ditchers provided with a special working machine (fig. 5) having a wide range of working speed and thus capable to diminish work loads on the machine assemblies. Very often to prevent deep freezing of the ground a strip of land corresponding to future ditch is preliminarily ploughed. Sometimes even a preliminary shallow ditch is dug and backfilled ahead of time.

Special rotary backfillers break lumps of ground frozen together and dump it into the trench (fig. 6).

During the winter construction great difficulties are encountered because of choking ditches up with snow. In such cases use is made of wheel ditches provided with scraper-loader hoist (fig. 7).

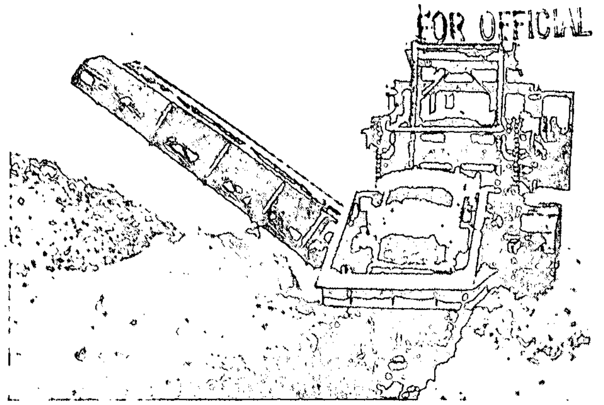

Fig. 5. Wheel ditcher with a special working machine for digging in frozen grounds

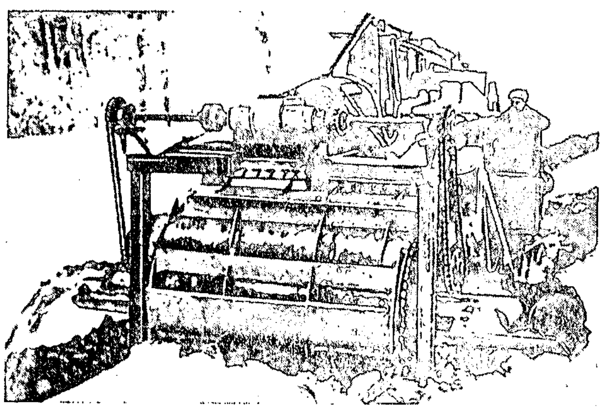

Fig. 6. Rotary backfiller for winter works

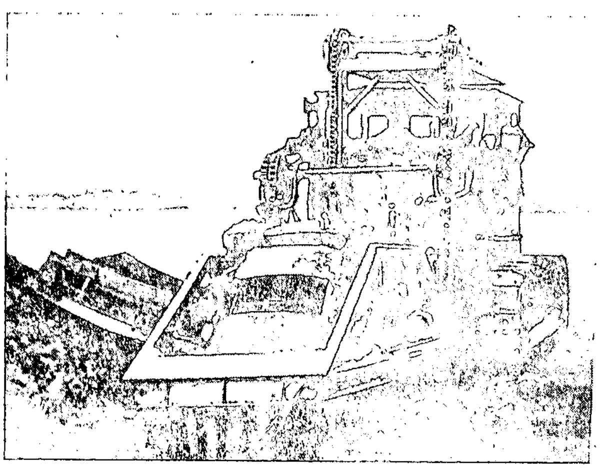

Fig. 7. Wheel ditcher with a scraper-loader hoist for clearing trenches of snow and crumbled ground

In laying pipelines across the swamps where carrying capacity of soil is too low for regular excavating machinery, use is made either of special ditchers with extra-wide tracks, or of riprap securing the pass of ditchers. In the swamp terrain the ditchers are done by draglines, by blasting or dredging.

V WELDING

In the past ten years in the U.S.S.R. different techniques of automatic and semi-automatic field welding of pipelines were developed and applied.

Pipes of 700—800 mm diameter delivered from mills in 12 m lengths are triple-jointed on special welding yards into 36 m sections. These yards are arranged either at the railheads or in the immediate vicinity to the right-of-way. It is economically advantageous to truck the sections jointed on the yard to a distance of not more than 30—40 km, and then to transfere the yard further along the right-of-way.

The pipes are jointed on special welding racks with pipe positioners and rollers. Pipes are welded as rolled with light automatic submerged-arc welding machines (fig. 8) at a rate of 35—40 m per hour. Welding current is supplied by tractor-mounted 600 amperes welding generators driven by the tractor internal combustion engine. Not long ago industry started manufacturing powerful 1 000 amperes welding generators enabling to raise the rate of welding to 60—70 m per hour. When jointing 700 mm pipes an operator assisted by a helper makes 50—60 welds per 7 hour shift — that is, 8—10 times more than by the manual arc welding. Welds produced by the automatic submerged arc welding machines have consistently high strength and are devoid of cracks, gas pockets, slag inclusions and other flaws.

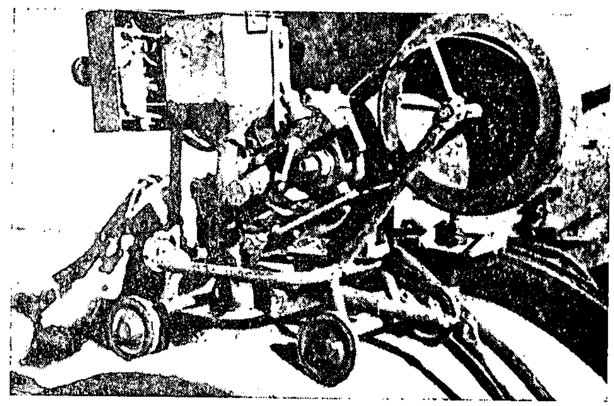

Fig. 8. Automatic submerged-arc welding machine »PT-56»

Side by side with automatic submerged-arc welding on yards a combined welding technique is used where the stringer bead is run in the CO_2-atmosphere while the second and the third passes are made with submerged arc welding machine.

Pipes and triple-jointed sections are strung along the right-of-way by heavy trucks with trailers (fig. 9—10). In the absence of roads, in swamp and broken terrain 36-m sections are strung by tractors with "Athey"-type trailers.

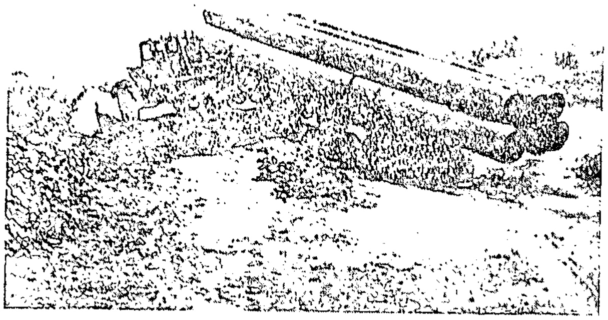

Fig. 9. Trucking pipes along right-of-way

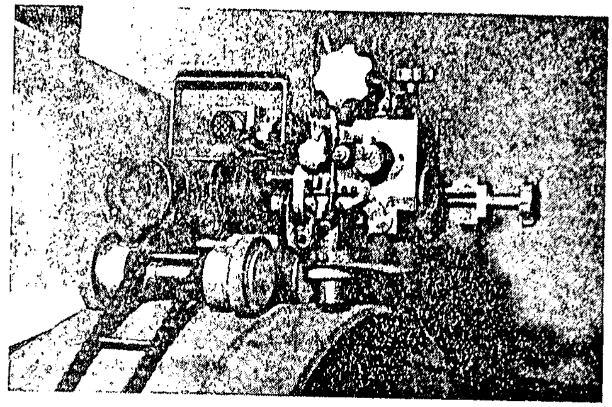

Fig. 11. Automatic CO_2-shielded arc welding machine for welding unrolled pipes

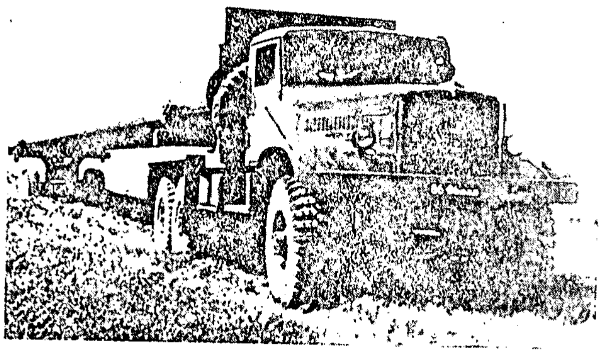

Fig. 10. Stringing 38 m long, 1020 mm diameter triple-jointed sections

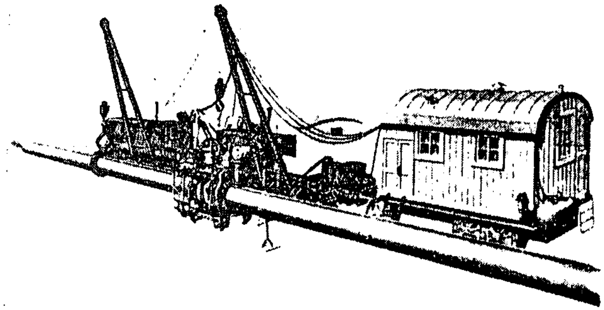

Fig. 12. Mobile electric flash welding aggregate

Very often non-rolled welding of pipes over the ditch is performed by the so-called downhead technique when each pass is run simultaneously by several welders. In such cases multipost mobile welding aggregates are used permitting to burn simultaneously two or three arcs.

Welding laboratory of the All-Union Research Institute for Pipeline Construction "VNIIST" has elaborated a new technique of automatic pipe welding in CO_2-atmosphere. In this technique pipes to be welded remain stationary while the automatic welding head rotates around them securing steady arc burning and multi-drop metal transfer (fig. 11).

For these automatic machines a special 1.2 mm Mn-Si steel wire electrodes are used. For regular weld fillet formation in all positions the wire is oscillated across the weld axis. Welding current of 120—200 amperes/mm², 18—22 volts is supplied by constant current-and-voltage generator. Pipes of large diameter are welded as a rule by two simultaneously working automatic or semi-automatic heads in two — three passes depending on the pipe wall thickness.

Pipes of 325—529 mm diameter are jointed by electric flash welding machines. E. O. Patton Institute of Electric Welding developed mobile electric flash welding aggregate (fig. 12) with belt transformers enabling to bring unit power down to 1.6—2.0 kWt/cm² of the cross section area of the edges being welded. Output required for welding pipes with 100—110 cm² wall cross section area is 160—200 kWt. A seven men welding crew makes 50 joints per shift. Nowadays experiments are made in electric butt flash welding of 720 mm pipes. Good economy of this welding technique permitted to recommend it for wide application in the field.

Welding inspection is of vital importance for pipeline construction. In the course of a few last years destructive tests made on a sampling basis were substituted by non-destructive methods of physical control. Radiography of welds with gamma-rays of radioactive Ir- and Cs- isotopes is being widely applied. Safety of the work with isotopes is secured by the use of distantly controlled containers of different design. At the same time proved to be very effective a magnetographic method of control with flaw recording on magnetic tape which is subsequently played back in special electronic ray tube apparatus (fig. 13). Welding flaws give rise to impulses seen at this tube, and by the amplitude and the shape of the impulse one can judge on the flaw size and character. Magnetographic method in comparison to radiography is 5—6 times cheaper and more efficient.

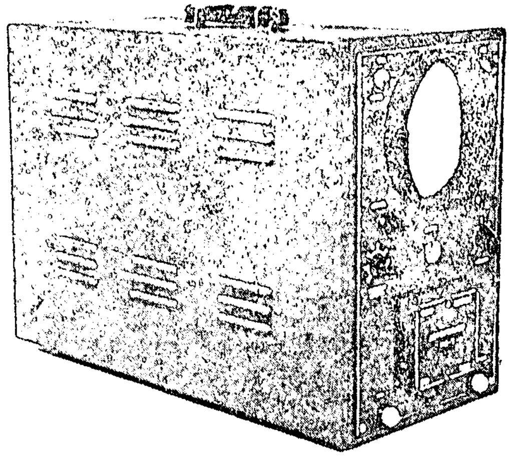

Fig. 13. Magnetographic welding flaw detector »MD-9»

VI COATING OF THE GAS LINES

All the buried gas lines are protected from soil and stray currents corrosion by coatings and cathodic installations. Nowadays pipe cleaning, coating and wrapping are performed directly on the right-of-way. Pipes are cleaned by line-mounted self-travelling machines, of which most commonly used are one-and-two-rotor machines OML (fig. 14) powered by 110 h.p. engines. As cleaning instruments scrapers, ball and flat brushes secured on the rotors are used. When cleaning 720 mm pipes productivity of the one-rotor machine amounts to 550—600 m per shift, and that of two-rotor machine — to 750—800 m per shift. Undergoing field tests are OBC cleaning machines with 40 h.p. engine. Cleaning instrument of these machines consists of 12 ball steel wire brushes rotating around their axis. Productivity of these machines averages 750 m per shift. The working instrument of the machines described is highly wearproof. Among the machines undergoing field tests are those which rotor is driven from power shaft of the side boom tractor, and those which rotor rotates on the shaft of an electric motor fed by the mobile electric power set rated at 60 kWt.

In the design stage are pipe cleaning machines with 1500—2000 m per shift capacity.

Of the anti-corrosion coatings those most commonly employed nowadays are asphalt-base enamels and »Bristol» tapes made of asphalt, asbestos powder, plasticizers and crushed rubber used as a filling agent (10—50 per cent of weight). In normal conditions enamel is applied in one coat 3 mm thick and wrapped by craft paper. In highly aggressive media coating system is strengthened. Before 1959 such heavy coating system consisted of two coats of asphalt each 3 mm thick, the first of which was wrapped by asphalt-saturated asbestos felt and the second — by craft paper. At present coating system applied in critical media consists of one coat of rubberized asphalt enamel, 3 mm thick, wrapped by »Brisol», 1.5 mm thick and by craft paper. For extra heavy coating use is made of 2.5 mm thick »Brisol» all other components being the same as in heavy coating. The modification of heavy and extra heavy coating systems design made coating operation less labour-consuming and facilitated its mechanization.

In the present-day practice of pipeline construction the following method is finding ever wider application. Welded continuous string of pipe is laid on ledgers not further than 2 m from the ditch. The first side-boom tractor accompanying pipe cleaning machines transfers the pipe to the ditch edge, and other pipelayers located in the section where the coating machine operates line the string up with the ditch axis and lay it down onto the ditch floor (fig. 15). Continuity of the coating is controlled by a flaw detector and its thickness — by a magnetic device.

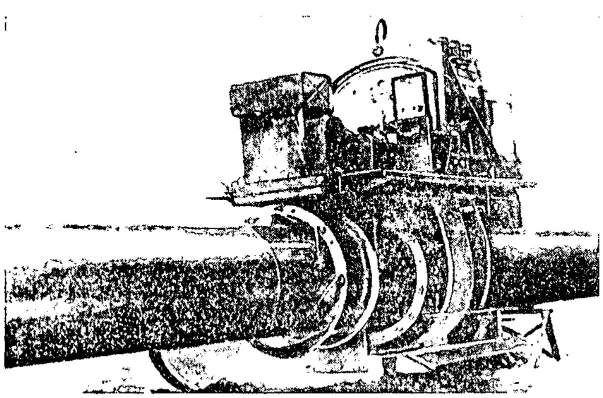

Fig. 14. Two-rotor pipe cleaning machine

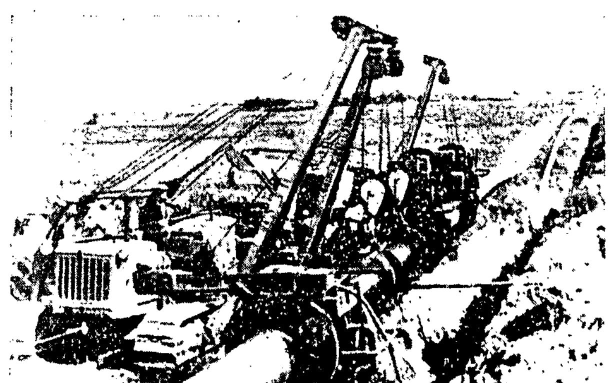

Fig. 15. Laying-in coated and wrapped pipeline

Asphalt base enamel is applied by self-travelling line-mounted machines spraying it through the ring nozzle or simply pouring the enamel on the upper part of the pipe and spreading in with brushes or slings. When applying one-coat heavy coating machines are provided with elastic cap helping to regulate the thickness of the enamel applied. Thanks to high efficiency of the coating machines coating crew goes ahead at a pace of up to 2000 m per shift (when laying a 820 mm pipeline).

Enamel is manufactured directly in the field on special yards having the melting pots and compounding equipment. Sometimes factory made rubberizes asphalt enamel is used which qualities make it acceptable for widely divergent climatic conditions.

Not rarely for corrosion protection of pipelines self-adhesive PVC tapes are used which are wrapped on the previously cleaned pipe by a relatively light machine (fig. 16). Its qualities make one coat of PVC tape 0.3 mm thick at least equivalent to a normal type coating system on a base of rubberized asphalt enamel. Heavy and extra heavy coatings are made with 50 per cent overlap providing the double coat of tape. Labour productivity when using this tape coating material increases two-fold.

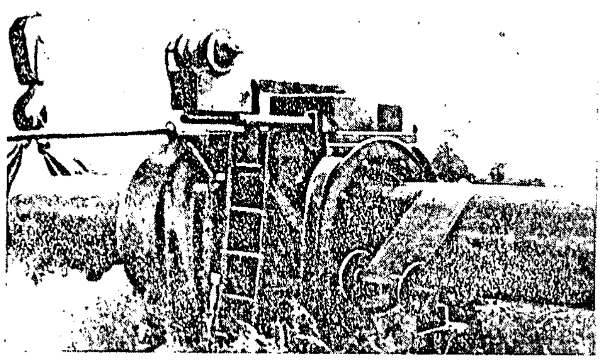

Fig. 16. Coating machine for PVC tape

Pipe coating directly on the right-of-way though almost completely mechanized still requires movement along the route of a great quantity of equipment and material. Sometimes weather presents serious difficulties not rarely causing interruption of the work. This stimulated the organization of semi-stationary coating yards where the 36 m long triple-jointed sections of pipe are coated with rubberized asphalt enamel and wrapped with fiberglass fabric or »Brisol».

Still the steady expansion of pipeline construction makes it prerequisite to organize mill-coating of the pipes. For this purpose a technique of mill coating of pipes heated in the process of their manufacture with PVC powder is elaborated. According to the economic estimates such a coating will be cheaper and better than traditional ones. Coating operation becomes considerably less labour-consuming.

A technique of electrostatic pipe painting with silicate enamels melted as painted by high frequency current is being tested on the mills.

Soil corrosion prevention of buried pipelines with the organic coatings is supplemented by electric protection by means of cathodic and sacrificial anodic installations. Capacity of the cathodic stations is determined by the pipeline size and organic coating quality. At present stations rated for 150, 300 and 600 watts are manufactured (fig. 17). If such a station lays far from outside power sources, electric power required is obtained from wind-driven or thermoelectric generators and galvanic anodes.

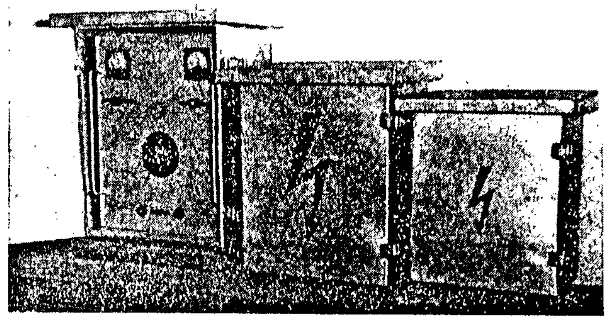

Fig. 17. Cathodic stations for 600, 300 and 150 watts

For pipeline protection against stray currents direct or polarized drainage installations, insulated joints etc. are used. They oppose the stray currents flow to the pipeline and drain off currents which had reached the pipe. Polarized drainage installations are rated for 100 (fig. 18) and 500 amperes.

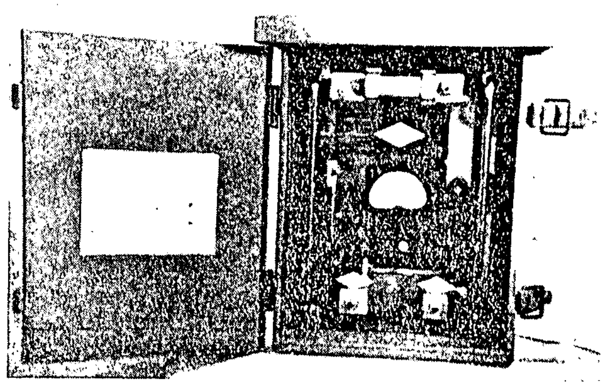

Fig. 18. 100-amp polarized drainage installation

VII PIPELINE CROSSINGS

Pipeline routes cross different natural and man-made obstacles which call forth different designs and construction techniques.

Cold bending of pipes for making changes in the direction of pipeline is performed by special pipe-bending machines (fig. 19). These machines are designed for bending definite sizes of pipe with the curvature radius of 6 m — for 219, 273 and 325 mm pipes, 7 m — for 426 mm, 12 m — for 524 mm, 30 m — for 720 and 820 mm, and 40 m — for 1020 mm pipes.

Railroad and highway crossings of pipelines are usually made underground either by driving or by horizontal boring (fig. 20).

Narrow rivers and ravines are crossed aerially on trestles (fig. 21). Across the wider rivers suspended aerial crossings are made. For instance crossing Amu-Daria river by two parallel 1020 mm gas lines is designed as suspended bridge.

Major river, lake, bay and strait crossings are laid mainly in floorbed. Subwater ditches are made by special equipment, in rock and heavy consolidated clay the blasting method is used.

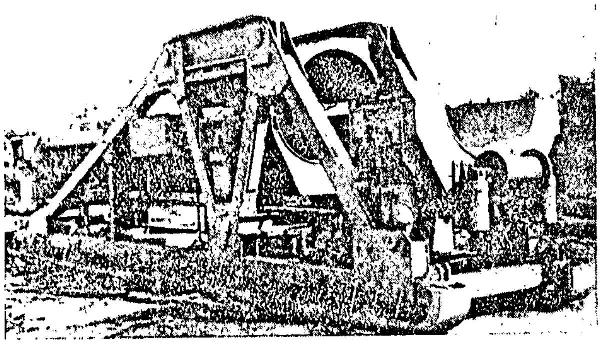

Fig. 19. Machine for bending 1020 mm pipes

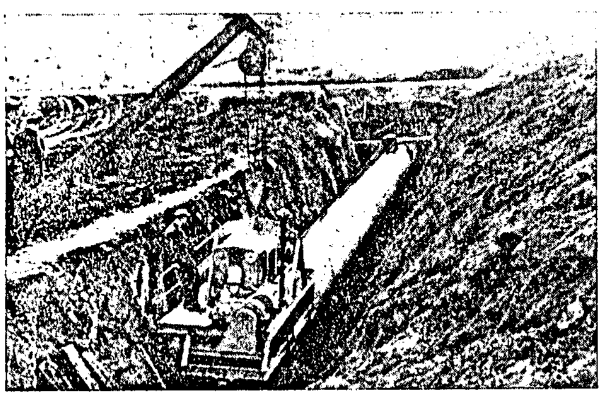

Fig. 20. Horizontal boring machine

On the navigable rivers dredgers capable of making ditched in 4.5—16.0 m deep waters are used. On the innavigable watercourses subwater trenches are excavated by draglines, by blasting etc.

Laying a pipeline into subwater trench is performed by pulling the whole welded string of pipe, by lengthwise welding and drowning from barges and so on.

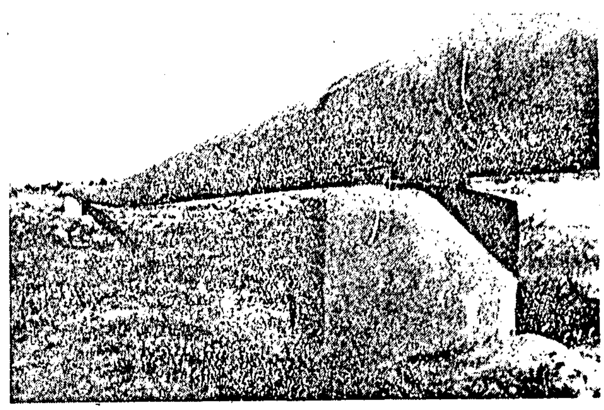

Fig. 21. Pipeline trestle crossing

Very often the negative buoyancy of pipelines is enlarged by reinforced concrete weights. For this job in many instances helicopters are used.

VIII CONSTRUCTION OF COMPRESSOR AND PRESSURE REGULATING STATIONS

Cost of compressor and pressure reducing stations, and other aboveground structures constitutes about 23—27 per cent of total initial cost of gas lines. Compressor stations are equipped with centrifugal gas turbine or electric motor driven compressors, and reciprocating turbocharged gas engine driven compressors. Type of compressor aggregate (compressor+prime mover) determines the general layout not only of the compressor building but of the station as a whole too.

Compressor station buildings are typified and erected of prefabricated elements. According to a standard layout scheme each station has two main buildings: technological and administrative (fig. 22). If on the technical reasons a certain item of equipment cannot be blocked with other machines building which houses this equipment may be erected separately. Still the total number of such separate buildings is not to exceed two or three for a station. As a rule these are small buildings incomparable in size with main ones. Blocking of the buildings and equipment permitted to diminish considerably station territory and length of station piping and other buried structures, and roads.

Water cooling towers are substituted by air cooling installations, vertical type dust separators give way to oil filters.

Compressor room together with personal accomodations is usually a two-span industrial-type building. Foundations for building frames and engines are made of cast-in-situ concrete. For columns, floor beams and crane runways prefabricated elements are used. It is planned to use prefabricated elements for foundations either. For curtain walls use is made of light panels with aluminum alloy carcass covered with asbestos-cement sheets and stuffed with mineral wool thermal insulating material (fig. 23). Typified panels are 6×1.2 m, their unit weight approximates 50 kg/m². Concrete foundations

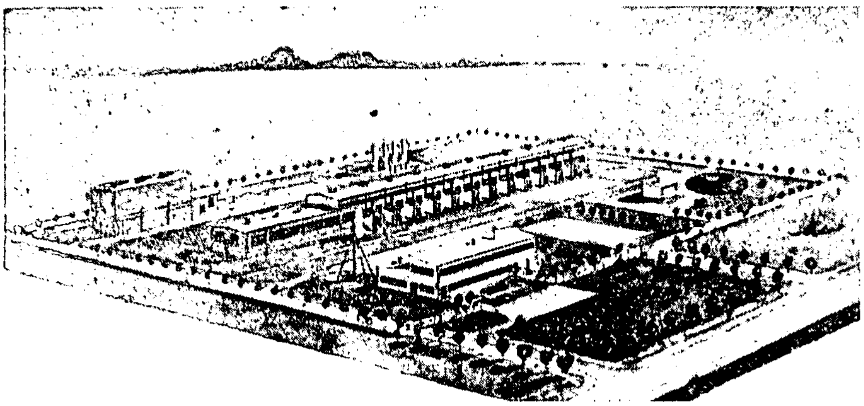

Fig. 22. Artist's view of 12 reciprocating compressors' station

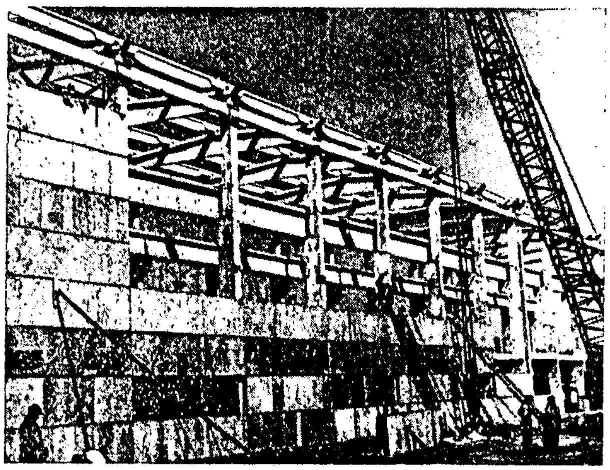

Fig. 23. Erection of frames and curtaining walls of compressor building

are cast in multiple-use inventory forms with conduits fixing wells for anchor bolts.

All the building and installation works are done in accordance with a schedule fixing the exact dates of starting and finishing certain stages of operations. Use of the prefabricated elements considerably speeds up the compressor stations construction.

IX CONCLUSION

Gas lines construction in the USSR is a scene of steady expansion. Total length of pipelines built in 1959 in comparison to 1950 increased six-fold. 3853 km of transmission gas lines were put in service in 1959, while in 1950—1955 length of the gas lines built amounted to only 3024 km.

Labour consumption in relation to 1 km of gas line considerably diminished, while outpup per worker increased. If in 1955 building 1,000,000 roubles worth of pipelines demanded 26 fulltime workers, in 1959 corresponding figure was only 15.

Raising the normal 7-hour day progress of the spread to 1.5—2.0 km demands modernization of building equipment. Construction of 1020 mm gas lines in particular stipulates the development of new machinery and new building techniques.

Systematic growth of pipeline construction makes it possible and advantageous to typify all the above-ground structures and buildings and line components (elbows, bends, valves, fittings etc.). Full realization of this typification program will result in still more considerable growth of labour productivity in the pipe line construction.

Quantitative and qualitative changes in gas line construction make it prerequisite to solve all the technical, organizational and economical problems in their interconnections as a unity. The main task of the research, design, industrial and building organizations is to speed up development and introduction into practice of more advanced techniques characterized by use of new better materials, machines and mechanisms, of better designs, and more rational organizational forms of construction leading to improving its economy.

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