FUNDAMENTALS OF STOVE CONSTRUCTION

In any hearth the hot gases coming out of the burner and moving inside it return their heat to the walls and after they are cooled they are discharged into the chimney. What is meant by the notion hearth? **The hearth includes a firebox in which the process of combustion of fuel takes place, and convection system to use the fuel heat** This may be the stove of any functional purpose (heating stove, heating and cooking stove, Russian stove, bath stove, etc.) stove with a fireplace, heating boiler.

While heating or burning of wood part of its substance is fumed, the other part remains on the hearth bottom. The quantity of matter which vaporizes from the wood, e.g. birch, reaches up to 88 %, and the quantity of solid matter amounts to 12 % only. The majority of the substance that vaporizes are combustible fumes, therefore in order to use the energy content efficiently combustion of these gases is also foreseen. The most common error while designing a hearth lies in the fact that one forgets about the existence of the gaseous fuel part of wood. Energy or heat content of wood is a maximum amount of chemical energy incorporated in it that theoretically can be separated from the fuel during its combustion.

Being guidied by this, we shall specify the following **concept**. In order to have a good hearth it is necessary to provide the following:

1. ensure the best conditions for the complete carrying out of combustion reaction, i.e. obtain maximum useful quantity of heat inherent in the fuel;
2. organize the natural movement of cold and hot gases, separate the gas flow coming through the hearth, direct the hot gases for heat accumulation and vent the cold ones;
3. fulfil the structural part of the convective system of the hearth in accordance with the necessary functional requirements in order to reduce the heat losses from the smoke fumes, ensure optimum heating of all parts of the hearth , turn the greatest part of wood energy content into useful heat, that is to achieve the highest efficiency factor. The possibility to use electric energy as reserve fuel.

Simplifying the gist of the concept: we have to obtain maximum heat from fuel combustion and accumulate the heat that was obtained in the hearth. The hearth design must meet the functional requirements and ensure optimum heat transfer.

These requirements are best of all met by the theory of stove construction worked out by I. S. Podgorodnikov. The most suitable conditions for carrying out the combustion reaction as well as organization of movement of the gases being cooled inside the hearth is to be solved on the basis of **natural (free) movement of gases**. The temperature of the exhaust hood fuel gases fed into the chimney is not big (something about 120 ° C) that conditions high thermotechnical capacities of the hood constructions. The efficiency factor of channel-free convection systems is 93. 7 % (do not mix up with the stove efficiency factor). The fundamentals of the right construction of household stoves have been worked out by I.S. Podgorodnikov on the basis of hydraulic theory of stoves, by the Russian scientist and metallurgist Prof. V. E. Grum-Grzhimailo. In order to better understand the question we shall view these fundamentals.

Provisions of hydraulic theory of stoves in regard to household stoves have fully preserved their meanings. The main idea underlying this theory is very simple. A hot gas plume surrounded by the cold gas comes up, as it is lighter, and a small stream-line of cold gas surrounded by the hot one goes down because it is heavier. V. E. Grum-Grzhimailo **while designing the stove recommends to set such a direction of movement of the gases in its every part that would correspond to their natural strive: a stream-line of hot gas**

surrounded by cold gas should be sent upwards, while the stream-line of cooling gas-downwards.

The hot gases coming from the firebox into the stove space are accumulated under the arch as they are light, forming, as Grum-Grzhimailo puts it, « a sack of hot gases». Cold gases being heavier, go down to the lower part of the stove, and in case they are not extracted they form
« a sack of cold gases». Therefore fume extraction should always be done at the bottom where the most cool gases are accumulated. The stoves built on this principle do not need «zigzag movement». The movement of gases in them is done by means of natural forces.
Such stoves are built using the principle of natural (« free», as M. V. Lomonosov puts it,) gas movement.

Refusal from zigzag movement made it possible to reduce considerably the resistance to gas movement inside the stove which is most important in the Russian stoves with quite a small height of the chimney. Only through the use of «free» (licentious) gas movement it became possible to solve the task of creating a heating furnace in the lower part of «teplushka» which chimney creates a reduced pressure of only 1.5-2 mm of water column. To solve this task using «zigzag movement» is practically impossible.

Flame flow coming out of fuel layer represents a mixture of burning gases stream-lines, air and products of combustion. In order the burning reaction in the flame ended, it is necessary to mix up its separate stream-lines; in the volume where the burning ends high temperature has to be maintained.

Underroof volume (at the top of hood) - «a sack of hot gases» is **an ideal combustion chamber**.

If the flame flow with the burning reactions which is not completely finished to let into the volume with low temperature, the gases will cool down , and the burning reaction will not be able to come to an end. In such gases there will be noncombustible carbon (soot) and resins left which will deposit on the walls of the stove channels through which the gases pass.

All stoves designed by I. S. Podgorodnikov look like a hood or two hoods located one over the other. A hood is a volume restrained by a continuous wall from the sides and from above. The hot gases are supplied into the hood from the bottom, the cooled gases are extracted through the holes also located in the lower part of the hood.

Turn the glass upside down and set inside a live cigarette from the bottom . You will see a smoke stream entering the glass, reaching its bottom, making a turn and going down in the form of a ring along its walls. The same gas movement takes place in the stoves built by the principle of hood.

When firing of the stove is finished and damper is not closed completely, the cold air coming through the firebox into the stove being heavier than the gases inside the stove, cannot go up and will immediately go into the offtake duct not carrying over a marked quantity of heat. Such a stove is built in such a way as if it had an automatic «gas» damper, excluding the possibility of hood cooling when the cold air comes into it. By this factor the ability of stove with hood (bell-type stove) to preserve heat for a long time even if the damper is not completely closed can be explained.

A great amount of fuel saving received after the conventional stoves have been replaced by the «double-deck hood» ones is explained by the very fact proved during practical tests that these stoves have got a «gas» damper.

1. A good household stove must meet the following **requirement**s:
2. The stove must have a high efficiency factor, i.e. about 75-85 %. If the firebox of the stove has equipped with fire grass, this requirement is met by the all known types of heating stoves.
3. The stove must be warmed up from bottom to top, wherein the bottom shall be more heated as the top. Such heating character must be observed during 48 hours. Due to this an equal heating of the lodgment will be ensured with the smallest temperature difference under the ceiling and on the floor.
4. The stove shall keep the heat and shall not cool down when the damper is not completely closed.
5. The stove shall not fracture.
6. The stove shall not get clogged with soot appearing due to insufficient fuel combustion.
7. The stove channels shall not get clogged with ash.
8. The stoves designed for the use in single storey houses shall differ by a minimum resistance to the gas movement.
9. The stove shall have a simple design.

The hydraulic theory of gas movement helped to get rid of «zigzag» movement, local resistance to movement of gases and direct the chimney energy for creation of negative pressure in cooking chamber and **breaking the negative pressure of gases in their movement from the backstone level to the floor.** The results proved to be touchy – the stove appeared to be simple with a strongly marked idea. This affords ground for believing that the «double-deck hood» stove will become the main type of heating stoves in the Soviet Union.

Being guided by the above mentioned concept and the outlines of the just construction of the household stoves by I. S. Podgorodnikov, let's specify the **main fundamentals for construction of hearth** having convection system without channels:

1. hood (lower and upper) can have any form, round, rectangular, Г-form, П-form, etc.;

2. it is not allowed to make continuous hoods within the deck (upper or lower) while the hood that follows will be less heated as the preceding hood. This condition was not taken into account by I. S. Podgorodnikov while designing the heating and cooking stoves IP 1 and IP 2. Due to this the rear wall of these stoves warms up far worse than the front one.

As a result, the above mentioned stoves have not been widely used. I improved the stoves IP1 and IP 2 (Russian Federation Patent No. 2055272 of February 27, 1996). It is possible to make parallel equal ranking hoods (uniform routes of gas movement);

3. the hood can be separated by horizontal baffle if it is necessary, doing so the best conditions for fuel combustion as well as separation of cold and hot gases streams shall be ensured; the separation using a baffle is necessary while designing Russian «teplushka», some of the constructions of bath stoves and heating boilers;

4. hoods with vertical splitting are not recommended; the stream of hot gases from the firebox

(or from the lower hood) flows with a great speed and widens while it comes up, the vertical splitting serve as a bar to the natural gas movement;

5. the lower hood in its volume may have variable cross-section and variable height (e.g. part of the hood volume has the height of one half of the stove, the other part - full height, whereas it is not allowed to install at the top of the upper part of the hood the summer flew damper as the smoke may go out through it);

6. from the upper part of the firebox it is possible to make one or several runouts of hot gases into the hood (preferably far away from the door) ; one should perform a **uniform** filling of the hood, if possible. The tracks for movement of gases in the hood until the connecting channel shall be made **equal in lenght**; the gases from the firebox may be guided into the hood upwards or aside. In order to avoid clogging of the stove it is not allowed to make an orifice on the back of the firebox lower than the twelfth row, apertures or seams without temper for passing of cold gases shall be foreseen;

7. the hot gases are fed to the second hood from the bottom, this is important, the hood filling shall be done **uniformly**, if possible. In some stoves which are recommended for building by the Gosstroj of Russia (State Committee of Architecture and Building affairs) as well as on the stoves using the «backflow» principle the hot gases are fed to the upper zone. Separation of the gas flow passing through the hearth is not taking place here, the hot and cold gases are forced to run through the upper part of the stove;

8. the oven should be placed higher if possible (in the upper zone of the hood), so as it would be washed by the hot gases at all sides;

9. the bottom of the lower hood is the first row (smoke fumes start to flow from the second row), this is possible in stoves built on the principle of the free movement of gases (the negative gas pressure is negotiated during the movement from the hearth level till the bottom). This provides a possibility to let the hot gases under the hearth bottom and the firebox; the height of the hood exit to the connecting channel shall be done at the bottom , three rows in height;

10. the external walls of the hoods must be of equal thickness along the whole perimeter; the hood shall hold the space along the inner walls and the lower part of the hearth, as well as under the firebox. The stove must warm up uniformly along the deck's perimeter starting from the first row (the basement shall be fireproof);

11. the hood may have one or more connecting channels, the latter may have one or more exits from the hood to the connecting channels;

12. the firebox shall not contain cold object (boiler, water tank, coiled pipe, etc.) while item 1 of the concept is not executed;

13. boiler, register, water tank, coiled pipe etc. are located outside the firebox, their elements can be located directly over the fire bars;

14. if a stove with a built-in boiler is used in the system of hot-water heating, it should be braced by a metal frame and insulated by inorganic heat-insulating materials from the outside; in case of using electricity for heating purposes, it is better to use a thermal

receiver (stove) instead of heat medium, the automatic use of economy mode at night is also foreseen;

15. in the heaths equipped with a system of hot-water heating, water heating is to be adjusted by changing the direction of the hot gases movement as well as changing the rate of the water circulation due to valve installation on the return pipe. A hood inside a hood is one of the means of water heating adjustment. The coiled pipe is installed in the small hood in the upper part of which there is a flap installed to control water heating, the small hood is located inside the big one;

16. the stove should be easily cleaned;

17. electric heaters shall be installed in the lower hood. A possibility of automatic using an economy night mode shall also be foreseen;

18. it is desirable that the thickness of the external walls of the stove firebox having a lower hood one row before the hotplate is 19 cm: by heating and cooking stoves - 7 cm lower than the hotplate, by heating stoves – 21 cm higher than the top of the firebox door;

19. in «double-deck hood» stoves one should use attachment pipes, the use of master and wall pipes is not recommended as the place of connection of the pipe and stove while heating and cooling the stove is subjected to fatigue action and may be broken; in case it is not possible to use attachment pipes the smoke branch pipes should have the so - called sheeting (corrugated) hinges, i.e. a movable joint;

20. the use of stoves built on the principle of the free movement of gases, having a small resistance to the movement of gases makes it possible to use one chimney outlet (pipe) for several stoves and fireplaces. This makes it possible to build double - or triple - deck stoves simultaneously working for one pipe.

Analysis of the work of some convection systems and designs of hearths from the point of view of the above mentioned «conception» and «requirements» of I.S. Podgorodnikov

Convection systems with series channels.

To this type belong stoves with vertical, horizontal, mixed (vertical and horizontal), hoisting and downhole channels located in one or two planes. Such stoves are usually done by the stove-setters of the old school. The main drawbacks are as follows: items 1,2,3 of the **conception** and items 2,3,4,5,6,7 of the **requirements of I.S.Podgorodnikov** are not observed. These systems cannot use electric energy as a reserve fuel.

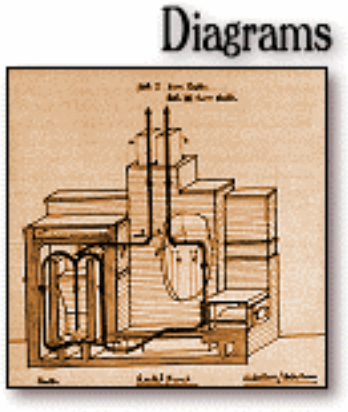
Parallel convection systems.

The gist is that the smoke fumes from the firebox go upwards to the ceiling through the channels, then they go down through several chimney channels and finally, are vented through the chimney.

The convection system can be single planed and multiplaned. Parallel convection systems have great advantages over the series systems. Their technical specifications are approaching to a single hood stove with convection system without using the channels.

However, these systems have some serious drawbacks. There is no free movement of the gases (separation of cold and hot gas streams), no «gas reel». Besides, the upper part of these stoves are best heated in comparison with the lower one (the same refers to a single hood stove as well), that affects negatively the thermal conditions of the lodgment in which a «pit» of cold air is being formed. These systems cannot use electric energy as a reserve fuel (upper heat penetration).

At present the majority of stoves built in the West are built on the basis of **counterflow.**
These stoves are a variation of the parallel convection system. The basic ideas consist in the the following: the stove channel (**the inner cladding**) connected with the firebox is separated from the stove casing by means of the «temper seams» n, therefore the most hot part of the stove has got movement freedom and does not depend on the other constructions of the stove; the smoke fumes are extracted through the chimney in the stove base, therefore the casing of the stove may move freely. The above mentioned stoves posess some marked advantages. Using of the inner refractory cladding made it possible to build the stoves with a very long service life. The stoves built on the principle of counterflow were being built more than 100 years.
At present there were practically no changes introduced to this construction. The activity in the field of invention was aimed at integration of different hearths into complexes and improvement of various parts of the hearth.



As an example one can admit a Chinese-Finnish stove (hearth) described in the magazine Advice of Professionals of February 2000 and a stove being built by the American company Maine Wood Heat Co. www.mainewoodheat.com Here attention is paid to functional capabilities of the stove and versatility of its use.

Combined convection systems.

To these systems according to the classification of A.E. Shkolnik (Stove heating in low-rise houses, Moscow « Vysshaya Shkola » 1991) belong the following stoves :

Preferably with low heating; with supply manifold with uniform dispensing; multicollector connection; series circuit. These systems have got a wide passing gases resistance ; there is no free movement of gases (separation of hot and cold gases flow), and there is no « gas reel». A great variety of these systems cannot use electric energy as reserve fuel.

Hood convection systems without channels

Previously we have spoken about the capabilities of the system. The main drawback lies in overheating of the upper part. It is easily eliminated by means of double-deck stoves « hood over hood», otherwise «double-deck hood» stoves. Besides, there is a necessity in low stoves, 15-20 rows, in which the influence of the upper overheat is not substantial.

The main advantage is a small inner resistance to the movement of gases, separation of the streams of hot and cold gases and, as a result, high thermal showings. Not a single convection system posesses these capabilities (advantages). If one compares the above mentioned convection systems one may say that the designing of multifunctional hearths operating on the

principle of a free movement of gases is on the starting stage of its development while the other systems have exhausted themselves.

This principle makes it possible to design stoves and consider all the requirements of the architect, the customer and constructive plans of the building. Only the use of the principle of the free (natural) movement of the gases made it possible to create a great variety of **multifunctional** stoves that are in ever greater demand, to combine the stove with the fireplace, wherein the walls of the fireplace are thoroughly warmed up, i.e. they are part of the stove.

In such combination the fireplaces and the stove can be operated simultaneously for one chimney. Moreover, this makes it possible to use a single exhaust channel (pipe) for several stoves and hearths, thus making it possible to build double- or triple-deck stoves simultaneously working for a single pipe.
Using these systems one can make an **inner refractory casing** in the lower hood (taking into consideration the principle of the free movement of gases), in other words, to introduce «western» technology used in stove construction on the principle of **counterflow.** Due to this the service life of the stove is getting longer. The design development of the **stoves of the type « double-deck hood» incorporating refractory casing will make it possible to create an ideal stove with a considerable service life.**

The analysis of the design of some hearths

Let's consider the **«Chinese-Finnish»** stove (hearth) already mentioned. The hearth includes a heating stove, hotplate with an oven, a stove-bench between them with a heating shield
(wall) , shelves; it has running hot-water. The hearth has got a combined convection system. The heating shield has a continuous convection system. The heating stove is made on the principle of counterflow (see diagram already shown). The heating shield has a continuous convection system. The heating stove and the hotplate can be fired separately or together; there are modes for the stove-bench heating and heating shield by means of the stove or the hotplate. The hotplate can be fired in a summer day.

The hearth advantages are as follows:
- functional value;
- long service life of the heating stove;
- the smoke fumes start to move from the second row;
- the stove walls have an equal thickness and are heated from the first row.

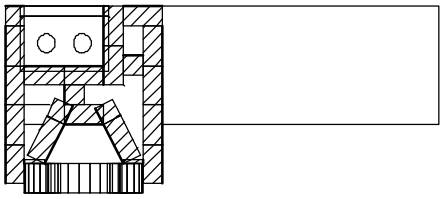
The hearth disadvantages are as follows:

- the necessity of simultaneously firing of the stove and hotplate to get the maximum convective heat exchange;
- complicated control;
- a non-uniform warming up while using separate firebox that reduces its crack resistance;
- from the heating stove the gases are fed to heat-exchange channels of the stove-bench and the heating shield preliminary machined (secondary) that reduces its heating and crack

resistance; besides, the approved convection system of the heating shield (series connected channels) is not effective;

- it has a great resistance in regard to the outcoming gases;
- the heating stove has an upper heating.

The hearth does not correspond to provisions of items 2,3 of the **concept** and items 2,3,4,6,7 of the **requirements** of I. S. Podgorodnikov.



Similar stove OVIK ZK 10L www.stove.da.ru designed by myself includes a heating and cooking stove, shelves above the hotplate, stove-bench and has one firebox. Besides, it has got a fireplace, it can be equipped with hot-water supply, oven and can be heated by the electricity. It has got a clear and a simple gas movement pattern. It fully corresponds to the **conception** and the **requirements** of I.S. Podgorodnikov. It is heated uniformly starting from the first row. It also has a summer variant of firing.

Before we come back to consideration of other stoves (hearths), let's consider the influence of the requirements of SniP (Building Standard of Russia) 2.04.05-91* on the thermotechnical performance of the stoves.

All type designs of the stove are made up in regard to the requirements of item 3.85, where the distances from the floor level (which are made from the inflammable and hard-inflammable materials) until the ashpan bottom is 140 mm, and the distance to bottom of internal heat channels is 210 mm (the base is fireproof). This requirement causes the reduction of the heat sink capability by 16 %. Besides, the thermal conditions of the lodgment are getting worse, as the very low layers are not heated thus leaving the floors cold. An effort to heat the floor leads to stoves overheat and overflow of fuel.

Considering the importance of the above information it is desirable to make a meaningful estimate of the given distances by means of laboratory research or to foresee other fireproof actions. **The stoves must be heated from the first row**. Western technology provides the gas flow starting from the second row (see the above mentioned Chinese-Finnish stove).

Items 3.65 (one stove shall be provided for heating not more than three lodgments...) and 3.70 (for each stove, as a rule , a separate chimney shall be provided...), **for residential individual buildings,** they are inadequate to the time being and emasculate the possibility of variations of the cubic task planning. For such residential buildings, in my opinion, it might be possible to allow heating of 4 lodgments using a single stove, it doesn't matter how many stoves are in operation on one stove. Our double- or triple-deck stoves with built-in fireplace have been successfully operated simultaneously for one chimney.

Let's view the performance of some type-design stoves recommended by the Gosstroj of Russia (series 1.193-1 and 1.193-2) and by some authors for the application.

Household heating stoves.

It is very characteristic that the majority of the stoves recommended for the application are purely hood stoves. This is another proof of the efficiency of the above mentioned stoves. They have some disadvantages in common: (OPTI-1, OPF-11 (PTO-4800), OPM-9 as well as PTO-2800, PTO-3100 (OPT-3), PTO-3300, PTO-4400 (OPT-9)) the presence of the inserts (splitting or partitions of the channels) in the hoods worsens their operations, the stoves are difficult to clean, «dry» joints (e.i. joints not filled with temper) or openings for cold gas passing are not provided in the firebox, the hot gases in this case are washed out from the lower hood. The wall-stove with extention combustion chamber (OVT 1) has got some horizontal channels which get blocked quickly.

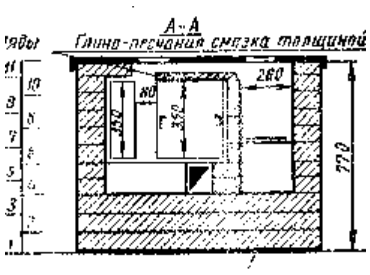
The stoves recommended by A. E. Shkolnik (Stove heating of low-rise buildings, Moscow «Vysshaya Shkola» 1991): PTO-2500 and PTOU-2500 have a series ineffective convection system. The PTO-3300 stove has a big height of zigzag movement in both hoods and, as a result, a reduced heat storage capacity. In the stove PTO-3900 the lower hood was misdesigned, the hood lenght (cross-section) is small, the cross-section of the connecting channel is big, and the height of the zigzag movement is big.

In the PTO- 4400 stove (OPT -9) besides the disadvantages already mentioned the lower hoods are placed too low. The same may be said about the interhood channel. This results in worsening of the stove performance.

The round stove PTO-2000 F (OTSF 1) meets all the requirements. The sample stoves PTO-5000 (OPT-10), PTO-5300, PTO-6000, PTO-2800 provided that temper seams or openings in the firebox for cold gases passing are made, also meet all the requirements. In the stove PTO-2800 the channel partitions in the upper hood shall be avoided.

The double-deck stoves (2 storey) that are shown in this book have the same drawbacks as their prototypes: PTD-2800/2600 (prototype PTO-2800),PTD-4400/3500 (PTO-3900), PTD-5400/5000 (PTO-5300). The sample industrial framed stoves are lacking openings or joints not filled with temper for cold gases to pass through. The «double-hood» stove 77x 77 cm designed by I. S. Podgorodnikov is really good.

Heating and cooking stoves.



1. The kitchen plates of series manufacture (KP-3, KP-4) have the following drawbacks:

Uneven oven heating (the smoke fumes circulate around it from three sides); the inner wall of the stove extension combustion chamber having the thickness ¼ of a brick and does not provide the heating to the required extent, neither does it provide durability of the extension combustion chamber. These plates are to be connected only to the chimneys. In case of their connection to the heating side wall the secondary exhaust gases do not provide the required heating of the side wall.

2. The kitchen plate KPOTCH with a side wall ia an absolutely non-operating stove.

The main drawbacks are as follows:

Besides the disadvantages already mentioned in item 1 it has two stove extension combustion chambers. In order to obtain maximum convective heat exchange it is necessary to fire the

stove and the plate simultaneously; in the winter firing mode of the plate the gases come to the side wall through the ashpan (which together with the channel from the plate are constantly blocked). In this mode thanks to the air inflow from the two doors the temperature of the exhaust gases in the plate goes down. Due to that the necessary heating of the side wall is not ensured. The side wall has an imperfect convection system (the top heating). Water heating cannot be controlled.
Meanwhile, the stove («double-deck hood») having the same functions and capacity but without the drawbacks can be easily solved.

3. The heating side wall OTCHK-1 is warmed up by the heat of gases coming from the kitchen plate. The design of the side wall and the plate cannot provide a uniform heating of the plate walls and that of the side wall while secondary exhaust gases penetrate to the side wall.
   The convection system of the side wall is incomplete.

4. The kitchen plates with a boiler KPV1, KPV 2.

   Placement of a cold boiler (object) in the firebox considerably reduces its temperature. Therefore a complete combustion of the gas component doesn't take place , thus resulting in the fact that the necessary heating of the heat transfer medium is not ensured.

   Using such a plate it is difficult to boil water.

5. The heating and cooking stoves SH-5 and SH-2 incorporate a combined convection system with bottom heating, with a forced movement of gases. They are less effective than the system «double-deck hood». The stove SH-2 has got some drawbacks covered in item 1.
   The SH-5 stove can be easily modified into a «double-deck hood». www.stove.da.ru

   Having considered everything that had been mentioned above, one can prove the statement said by I. S. Podgorodnikov 40 years ago: « The « double-deck hood» stove will be the most widely spread type of stove in the Soviet Union», applying this saying to modern conditions.

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