THE EFFECT OF SHOT PEENING ON THE THERMODYNAMIC PROPERTIES OF PIPING

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ABSTRACT

Shot peening increases not only the mechanical abilities of metallic items but their thermodynamic properties as well.
This knowledge and the research results are very important to designers and calculators of heat exchangers, boilers and other heating or cooling units.
Of course, it is necessary to take into consideration a complete cost of the final product, since the heat transfer from one fluid to another over a bundle of different types of tubes is a very important surface.
With shot peening on the inside-outside tube surface the surfaces important for heat exchange can be increased, and consequently conductivity evidently changed.
To this scope lots of testing, measurements, comparing, controlling and approvals of different thermic coefficients are necessary.

KEYWORDS
metallic items, thermodynamic properties, outside-inside surfaces, pipes, boilers, heat exchangers, heat transfer

INTRODUCTION

It is interesting to learn the effect of shot peening on the properties of piping surfaces.
After shot peening internal and external surfaces submit changes, where produced roughness means increased surface which then becomes important in heat transfer of heat exchangers and boilers.
It is evident that external and internal surfaces of pipes transfer heat from one fluid to another, and that after experiments with shot peening better results on both surfaces are registered.
First it is necessary to make functional analyses and further modelling, calculations and evaluations, what then allows for establishing a model.

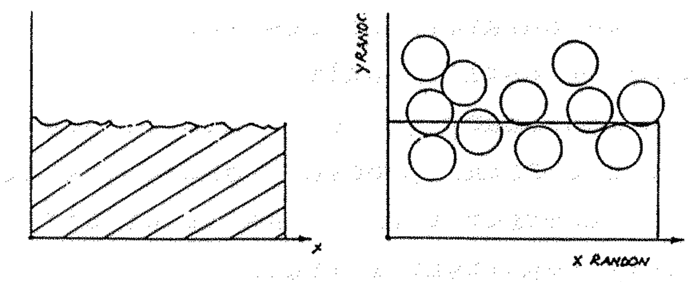


FIG 1 SIMULATION OF IMPACTED PIPE SURFACES

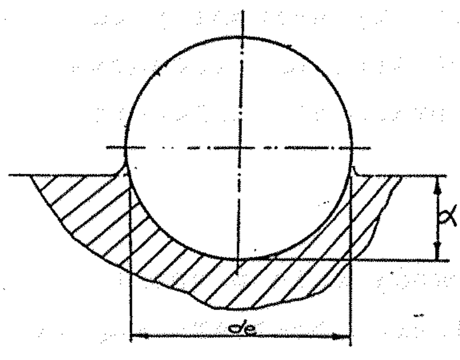


FIG 2 IMPACT OF SHOT ON METALLIC SURFACE

Figures 1,2 represent the first phase of modelling to be determined by impact contour with depth produced by the shock of one shot hammering on metallic surface.

$$\alpha = v_{part}(x_0)\cdot\sqrt{\frac{m_{part}}{3\cdot\pi\cdot\sigma_f + d_{part}}}\cdot K \qquad (1)$$

$$d_e = 2\sqrt{\alpha\cdot d_{part} - \alpha^2} \qquad (2)$$

σ_f = yield point

K = correction factor

de= diameter of part of spheroid body impacting below metallic surface

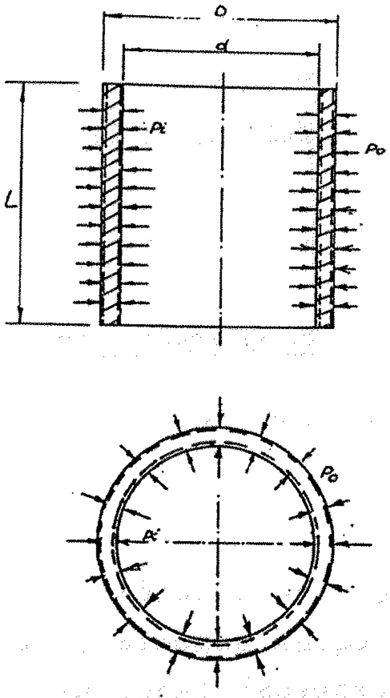


FIG.3. SHOT PEENING OF INTERNAL AND EXTERNAL SURFACES OF PIPE (BETTERMENT OF COEFFICIENT CONDUCTIVITY λ.)

After peening the remaining metallic surface presents increased roughness. This depends on peening randoms in axes y and x, what is determined by surface element.

Depth is in function of velocity (v), mass (m) and diameter of departing shot and degree of increased hardness on the piping surface, where both surfaces are treated under shot pressures Po and Pi.

It is logical that an effect is visible with some face deflection on the outside and the inside.

In heat exchangers or boilers the piping system serves for heating or cooling fluids, e.g. water, oil, crude oil, etc.

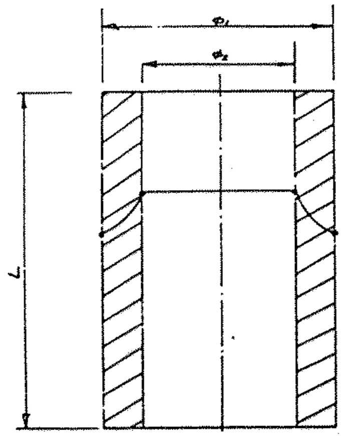


FIG. 4 THERMAL CONDUCTIVITY IN PIPE WALLS

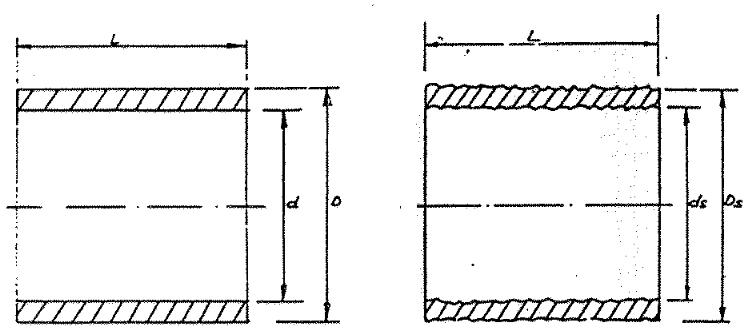


FIG 5 COMPARISON BETWEEN NORMAL AND TREATED PIPE

In Fig. 4 it is visible that the outside fluid receives heating, and that on internal faces equal temperatures are registered, while temperatures on the external faces are lower than the internal ones.

It is also evident that heat transfer depends on resistance of pipe material, and conductivity of heating depends on thickness of pipe material.

Thermal resistance of the pipe is illustrated by equation 3

$$\frac{1}{K} = \frac{\ln \phi_1/2 + 1}{\phi_1/2} \Big/ 2\pi \cdot \lambda_i \cdot L \quad (3)$$

$$\frac{1}{K} = \sum \frac{\dfrac{\ln \phi_1/2+1}{\phi_i/2}}{2\pi \cdot \lambda_i \cdot L} \quad (4)$$

$$K = \frac{2\pi \cdot L}{\sum \frac{1}{\lambda_i} \ln \frac{\phi_i/2+1}{\phi_1/2}} \quad (5)$$

where total resistance and conductivity will be as in Fig.5.

internal fluid in the pipe is transferred on the outside face of the pipe. By this, we can calculate entry heat and exit heat. Theoretically, if we look at a unit of space receiving heat in this way on the three spatial axes x, y and z, we can see:

$$\text{Entry heat: } dQe = dQex + dQey + dQez = \lambda x \frac{\partial \theta}{\partial x} dydzdt - \lambda y \frac{\partial \theta}{\partial y} dxdzdt - \lambda z \frac{\partial \theta}{\partial z} dxdydt \qquad (6)$$

where

θ = mathematical expression for heating, and

$\lambda x,y,z$ = coefficients of conductivity.

This differential equation represents thermal entry in the pipe, as well as thermal exit of the pipe, where

$$dQo = dQox + dQoy + dQoz \qquad (7)$$

The conductivity of three axes x,y and z must equal, i.e.

$$\lambda x = \lambda y = \lambda z \qquad (8)$$

Finally, the difference between entry and exit quantity of heat is got, and final equation is

$$dE = dQe - dQo \qquad (9)$$

where this difference is shown.

If, instead of normal technical pipe, we have the pipe treated by shot peening, as in Fig. 5, it is evident that the normal pipe and the treated one present differences on outside and inside surfaces.

The total of both surfaces in treated pipe is:

$$Fs = Ds \cdot \pi \cdot L + d_s \cdot \pi \cdot L = L \cdot \pi (D_s + d_s) \quad [mm^2] \qquad (10)$$

whereas in normal non treated one is:

$$F = D \cdot \pi \cdot L + d \cdot \pi \cdot L = L \cdot \pi (D + d) \quad [mm^2] \qquad (11)$$

After this, it is clear that the treated surface is greater than the untreated one, what means

$$Fs > F \qquad (12)$$

The above equations show that shot peening helps increasing the active surface for heat transfer, and eventually the effectivness of heat exchangers, what is epscially respected and valued by designers of boilers and heat exchangers.

areas covered with inclined lines,i.e. higher temperatures when pssing such a bundle of pipes lose some quantity of heat, what is usual in classic thermal vessels, whereas peened pipes,with increased internal and external surfaces, register an increased exchange of heat, what is presented by small areas between two curves.

In Fig. 8. curves represent heat exchange in a plant with two fluids going in the opposite direction at the point registered as best for heat exchange. Here we register the coefficient of transmission of heat of two liquids between thickness of the pipe, and the standard calculation on thermal resistence coefficient is:

$$\frac{1}{k} = \frac{1}{\alpha_1} + \frac{1}{\alpha_2} + \frac{s}{\lambda} \qquad (13)$$

where

α_1, α_2 = coefficients of heat transfer in laminar streaming of two sample liquids

s = thickness of pipe walls, and

λ = conductivity coefficient.

The total quantity of heat to be changed is:

$$Q = K \cdot S \frac{\Delta\Theta' - \Delta\Theta''}{\ln \frac{\Delta\Theta'}{\Delta\Theta''}} \qquad (14)$$

and

$$\Delta\Theta_m = \frac{\Delta\Theta' - \Delta\Theta''}{\ln \frac{\Delta\Theta'}{\Delta\Theta''}} \qquad Q = K \cdot S \cdot \Delta m \qquad (15)$$

which expresses mean logarithmic temperatures.

It is evident that the total quantity of heat exchange is increased, because the total of pipe surfaces has undergone shot peening treatment.

It is necessary to examine and test different types of pipes (e.g. for boilers, heat exchangers, aircollers), or different types of thermal units to be able to prove the positive effects of shot peening.

Other advantages of shot peening process over the standard production of pipes are:

- increased hardness due to residual stresses in the pipe body,
- increasedlife of the pipe
- fatigue strength factor risen
- life of operation prolonged
- cracking diminished
- corrosion stresses postponed.

If we, during the construction of boilers and heat exchangers, use pipes treated by shot peening beforehand, we will surely get more effective heat exchange, because the surface of heat flow has been geometrically increased.
It is also evident that the greater the surface the bigger the quantity of heating.

The effect of shot peening process on piping bundle in boilers or heat exchangers is illustrated in Fig. 6:

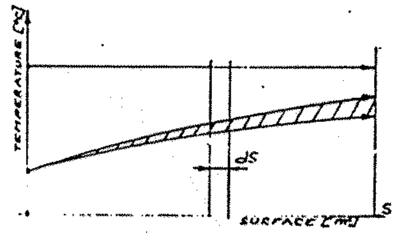


FIG. 6 IN THE CASE WHEN ONE FLUID NOT CHANGING TEMPERATURE

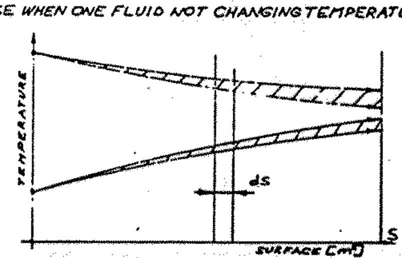


FIG. 7 IN THE CASE BOTH FLUIDS IN SAME DIRECTION

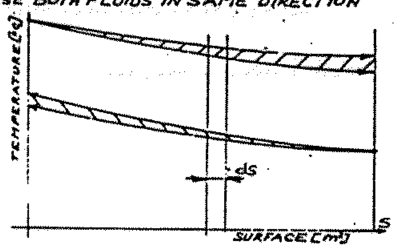


FIG. 8 IN THE CASE BOTH FLUIDS IN CONTRARY DIRECTION

Vertical axes represent temperature values while horizontal ones represent surfaces.
The upper horizontal line represents the level of temperatures constant, i.e. the fluid does not change temperature, and keeps the required constant temperature by adding some heat, as shown by curve from left to right.

Figure 7. represents a heat exchanger operating on two liquid fluids having the same direction and taking and letting out a certain amount of heat. Both liquids are at different levels of temperature - higher and lower: the higher giving heat and reaching the right value, the lower one by taking temperature getting to higher degree.
With shot peened pipe there are some differences presented in the

Other positive effects on piping properties are shown in Fig. 9., where classical curve shows functions of the residual stresses depth.

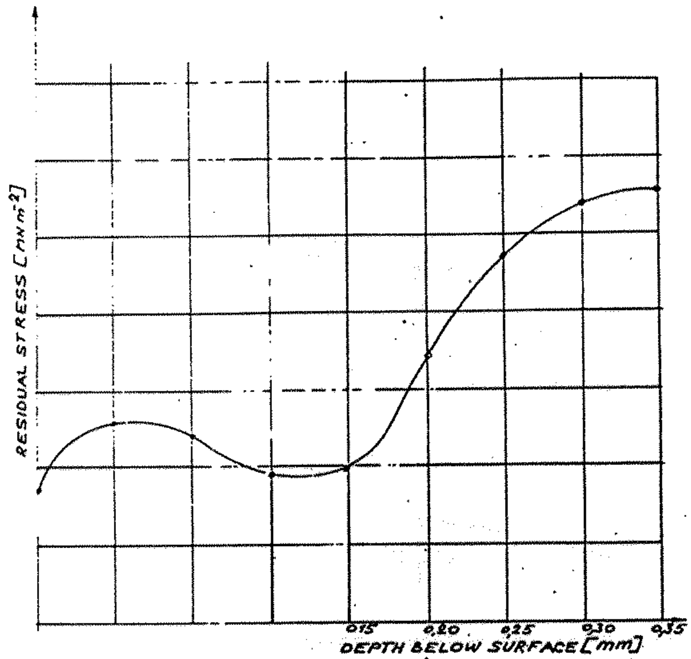


FIG. 9. DEPTH CREATED BY SHOTS AND RESIDUAL STRESS

DEVICES FOR SHOT PEENING APPLICATION ON PIPING

Industrial plants require thermal improvement of existing piping, and that is where shot peening is necessary, since its benefits can be felt in increased coefficients α, λ, k, as well as on all external and internal surfaces.

This paper investigates the research to be carried out on different piping systems treated by shot peening.
It is also necessary to take into consideration the pipes mostly used in heat exchangers or boilers.
Even without any further investigations or research, it is evident that the surface of heat transfer is the most important factor, i.e. greater surface unables greater quantity of heat exchange, which then means more units getting more heat, or eventually reducing production cost.

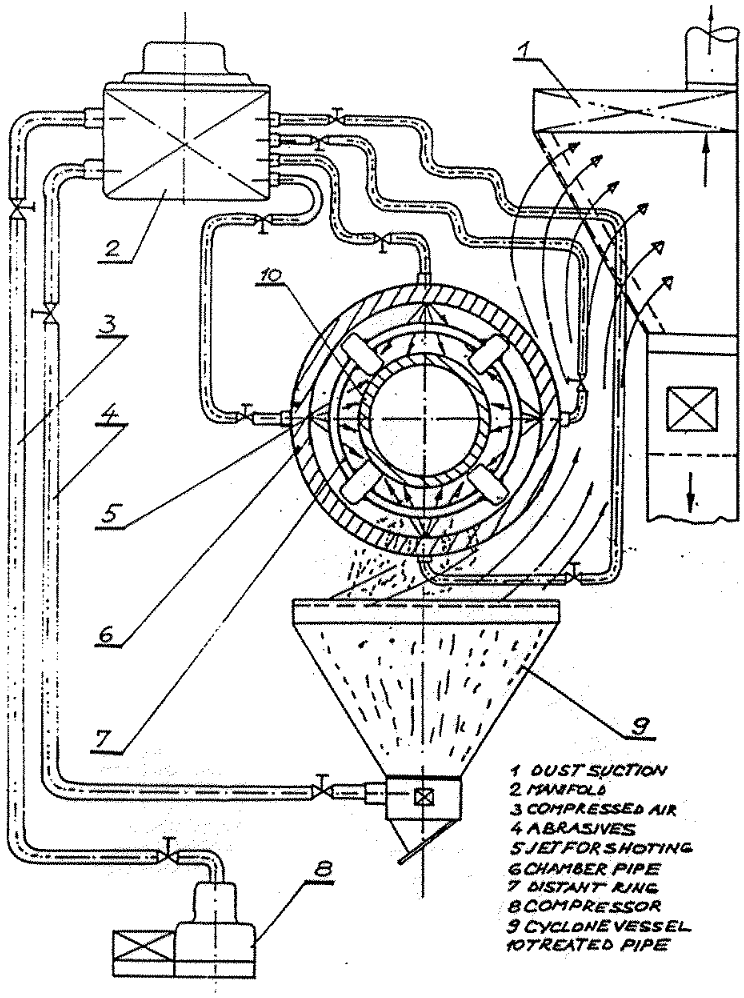


FIG. 10. SCHEME OF SHOT PEENING ON EXTERNAL SURFACE OF PIPE

Each designer of boilers or heatexchangers, in respect of reducing material cost, should keep that in mind when esimating the advantages of thermal units treated by peening.
Comparison with standard plants is necessary to prove the improvements and benefits offered by shot peening.
Devices and tools enabling shot peening process are to be provided for.
The above figure (10) shows a device for shot peening on the external pipe surface. The external fixed pipe serves as a chamber for the treated pipe which is moved in and rotated by a distant ring. Cyclone overtakes residuals for further process, and ventilation system is in function of dust suction.

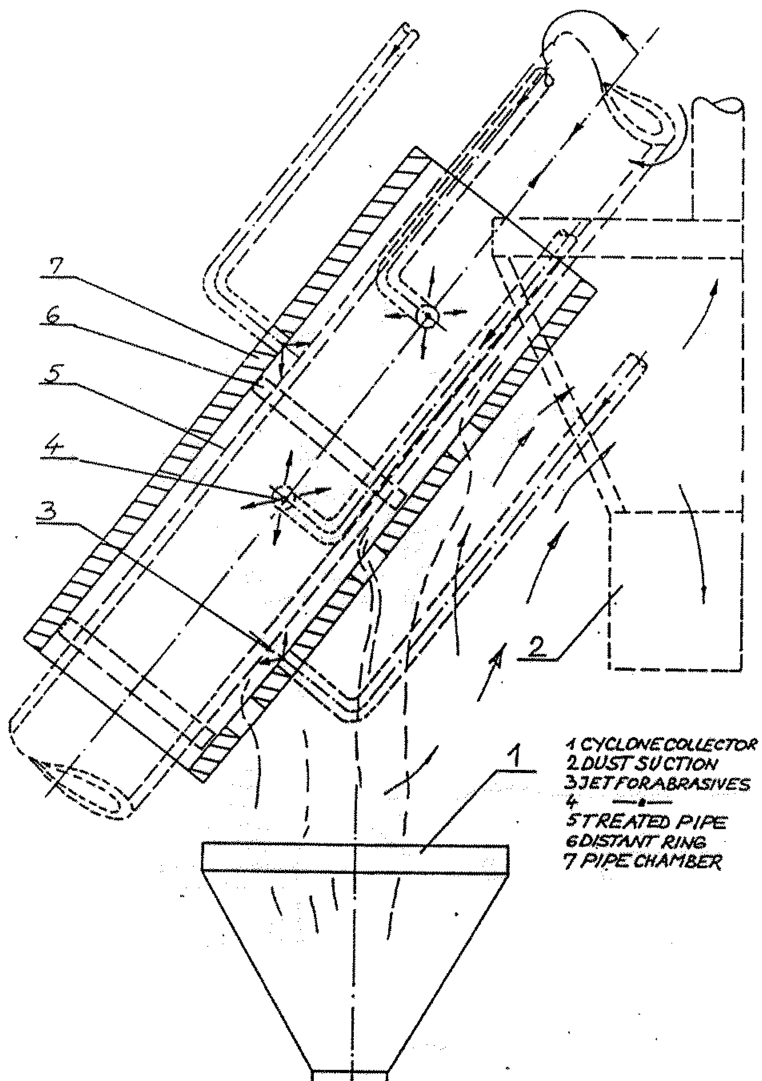


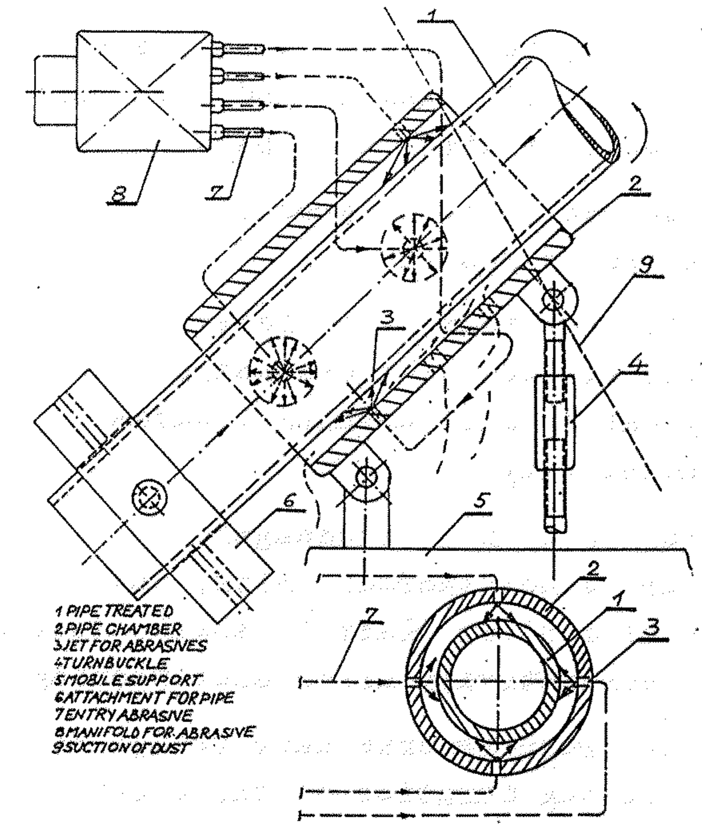
FIG 11. DETAILS OF CHAMBER PIPE FOR SHOT PEENING

Figures 11,12 represent the pipe shot peened on the outside surface, with all necessary items indicated.

Figure 13. shows a device for shot peening on inside surfaces by means of a small tubing with jets for abrasive hammering on the surfaces, which then is rotated by paired rolls on mobile supports, with a possibility of inclination by sliding and turnbuckles.

Dust suction is carried out by fans, and must be provided for to remove all dust from the working area.

FIG 12 — SCHEME OF SHOT PEENING ON THE OUTSIDE SURFACE OF PIPE



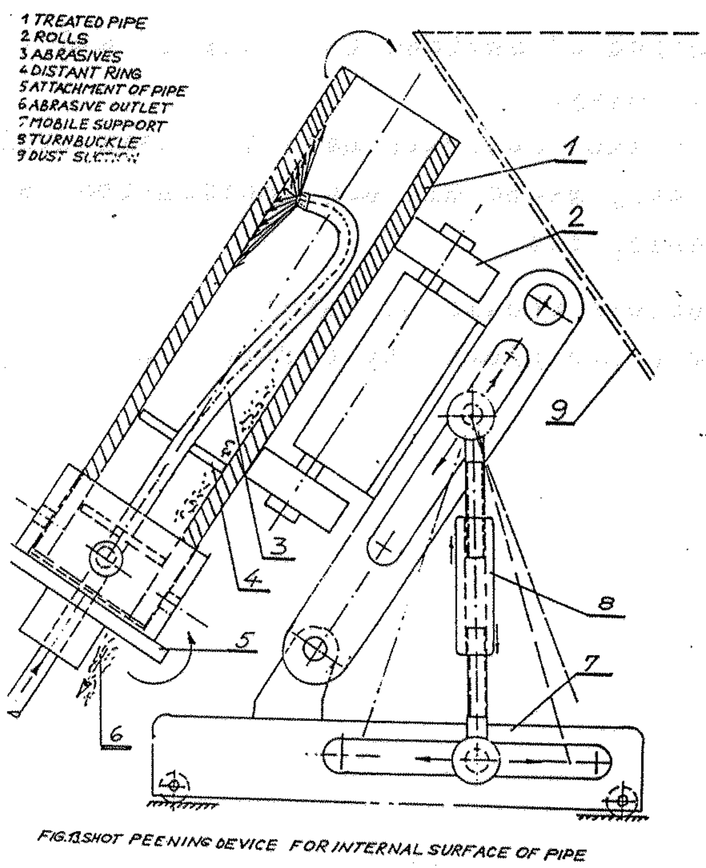


FIG.13 SHOT PEENING DEVICE FOR INTERNAL SURFACE OF PIPE

CONCLUSION

All so far exposed is just the basis for furhter research and testing to get results of how different coefficients are important in heat transfer and heat conductivity from one fluid to another after shot peening pipe process.

There would be necessity to produce standardized sheets and forms for recording results.

Without any further testing it is evident that steel or any other metallic surface will demonstrate better thermal conductivity after shot peening treatment, as well as better electric conductivity.

The manufacturers of heat exchangers, boilers, steam generators, pressurized and other thermal units, should be interested in construction of a pilot plant to enable testing of heat transfer and conductivity after shot peening.

Some mechanical requirements have though to be fulfilled and improved to prolong duration of the plant operation life thus decreasing costs.

The construction of devices for outside and inside shot peening is simple and easy.
Most metallic manufacturers have in their workshops piping systems for compressed air and ventilation, which are essentials for shot peening too.

All these factors should be taken into consideration when constructing a new plant to assure that the goal be achieved.

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