My invention relates to sulphur mining, but more particularly to the mining of subterranean deposits of sulphur by means of hot fluid which when forced into the sulphur bearing stratum through deep wells acts as a medium to fuse the sulphur which when melted is pumped to the surface in its liquid state.

The underground deposits of sulphur occurring particularly in the upper structures of the salt domes found in Louisiana and Texas, along the coast of the Gulf of Mexico, are located beneath water bearing sands. The sulphur occurs in a water flooded porous lime and gypsum rock which becomes connected with the water sands above through cavities incidental to the application of heat in the mining process.

Methods heretofore in use have employed heated water under pressure, the melting point of sulphur being above the boiling point of water sufficient pressure had to be maintained to prevent the heated water from vaporizing. In actual experience with existing mines the following has been found to occur: Cold water has a greater density than hot water. Due to this fact whenever hot water is pumped into the sulphur bearing zones the heavier cold water present in the porous rock and the sands above immediately flow down into the sulphur cavity forcing the lighter hot water out of the sulphur strata into the overlying sands entirely barren of sulphur. This migration of the valuable sulphur melting vehicle from the native site of the sulphur deposit almost entirely vitiates the efforts to melt the sulphur. This makes the hot water process of heating and fusing of the sulphur physically ineffectual and superlatively expensive due to the waste of the predominant proportion of the thermal units which are carried off by this water escaping into the upper sands. To secure workable results in maintaining any of the heated water in contact with the sulphur in the formation in the prevailing technique of mine operation it is found necessary to pump immense quantities of hot water into the mine and to depend more or less on accident for results. In consequence of which, even in the best of recoveries, seldom if ever does the thermal efficiency of the cycle exceed 5%.

It is one of the objects of my invention to so regulate the specific gravity of and manipulate the flow of the heated fluid in the mine so that it cannot be displaced by the cold ground water, and may be directed to the level desired.

Another object is to systematize the introduction of the heated fluid into the strata so that the maximum heating effect is imparted to the sulphur.

Still another object is to employ a fluid having a density which will cause it to rise with respect to the ground water while it is heated, but such that as it becomes partially cooled it will be of greater density than the ground water and will sink to the lower surface of the sulphur strata.

It is also an object to vary the density of the fluid used to heat the sulphur strata in accordance with the density of the ground water already in this porous strata so that the fluid may reach the desired point, either at or above or below the point of discharge of said fluid.

I aim also to provide a plurality of adjacent test wells whereby the density of the strata content can be constantly obtained and to thereby control the flow of the heated fluid being introduced and observe the operations which occur in the mine.

Other and further objects of my improved method and arrangement will be readily apparent to those skilled in the art to which it appertains when the following description is considered in connection with the drawing wherein:

The figure shown illustrates a cross section of the geological formations usually encountered in sulphur bearing localities and showing the arrangement of the several wells and test openings which I contemplate using to carry out my improved procedure.

This application is in the nature of a substitute for my prior application, Serial No. 28,020 filed May 4th, 1925, for a method of mining sulphur. It also relates in some respects to the subject matter of my Patent...
But is specifically an improvement over either of these disclosures. The drawing herewith illustrates the various formations, 1 indicating alluvium soil, 2 a shale clay; 3 a water sand; 4 another shale clay; 5 gypsum; 6 sulphur; and 7 a salt deposit. The porous openings at 8 are usually filled with the ground water which I have shown for purposes of illustration as divided into three zones A, B and C. Obviously as many zones may be created as desired depending on the size of the dome, the quantity and location of the sulphur and the temperature and density of the ground water encountered. The drawing also shows two wells as having been drilled into each zone as shown at A', A'', B', B'', C' and C''. The sulphur deposit is in a mound formation of which I have shown approximately one half.

The various wells in order to reach the sulphur strata are therefore of different depths and it is due to the mound formation of the sulphur that I am enabled to practice the method about to be described.

The sulphur as found in the usual mounds is in yellow orthorhombic crystalline form usually at a temperature of about 90°F, and when pure has a specific gravity about 2.06. The sulphur melts at about 239°F, and remains in a mobile liquid form until a temperature of 340°F, is reached whereupon it assumes a semi-solid gummy character passing into an amorphous form which cannot be readily handled. Thus the sulphur must be heated to a temperature of at least 239°F, but may not be above 340°F, if satisfactory removal is to be obtained.

The boiling point of water at atmospheric pressure is well known to be 212°F. Certain prior processes of obtaining sulphur recommend raising the boiling point of water by the addition of "salt" in an attempt to reach the melting point of sulphur. Standard tables however state that a saturated solution of sodium chloride and water will have a boiling point of about 227°F. Thus it would seem to be obviously impossible to obtain a solution of salt and water having a temperature of 289°F, which would melt the sulphur. It is also known that by placing the water under pressure any desired temperature needed to melt the sulphur may be obtained, so that the common process now employed in mining sulphur is to super heat pure water and use no salt solution.

The superheated water under pressure is then forced into the strata, but with the inefficient results which I have heretofore set out. In my Patent No. 1,648,210, I disclose a method for the displacement of all the ground water in the strata by a heavy density fluid and then the gradual withdrawal of this fluid. This method, however, requires an enormous amount of heavy density fluid to displace the resident ground water and I have, therefore, devised the present method of operation.

The ground water in the mines, due to minerals and other substances in solution, has been found to have a specific gravity of about 1.01 and a temperature of about 90°F. Pure water at a similar temperature has a specific gravity of .995; at 240°F, the specific gravity of pure water is .947 and at 340°F is .898.

I contemplate introducing a solution of fluid which at high temperatures is lighter than the ground water, but which is heavier than the ground water as the solution is cooled.

There are various fluids and materials which may be used to make up such a solution, but the most economical is a solution of water and sodium chloride. I have found that a 13% salt solution has a density about 10% greater than pure water at the same temperature and that a 7% solution is approximately 5% greater density. I contemplate introducing into the mine such solutions as these in a superheated condition under pressure and at a temperature of about 340°F. The ground water at 90°F is approximately 5% heavier when the same water is heated to 240°F, and is about 10% heavier than at 340°F.

The ideal solution to be placed in the mine would be one which would rise from the point of introduction to contact the upper strata of sulphur and melt it. The water continuing to rise so long as it remained above a temperature of 240°F, but would have a density which would permit it to descend as soon as it cooled off to a temperature below 240°F. Thus it would then descend to the lower strata of sulphur which would be gradually heated for application later on of a hot fluid. In this manner the maximum heating of the sulphur would be obtained.

I have found that with solutions of salt and water varying from 5 to 13%, I am enabled to obtain densities which will rise in the mine as long as they are above a temperature of 240°F. When co-mingled with ground water, but which will gradually descend below the ground water as the temperature falls below 240°F. However, in order to be able to ascertain constantly the changing temperatures and densities of the ground water, solution introduced, and the mixture of the two, it is necessary to arrange a series of wells to take periodic tests for the information of the operator. By drilling a series of wells such as illustrated in the drawing I am enabled to obtain the dip and strike of the strata. I then obtain the temperature and densities of the ground water at each well. With this information I can introduce a heated solution say in the well A'. This solution will rise, melting the adjacent sulphur which may then be withdrawn thru the usual eduction tube which is smaller and...
concentric with the well casing thru which the solution is introduced. The solution upon cooling, however, due to greater density, will settle and gradually descend down the slope of the strata warming the sulphur below. By taking tests at the well A" I am enabled to observe the procedure of this solution. At an opportune period heated solution may next be introduced into well A" and observations taken at A' and B'. This alternate observation and introduction of solution may progress over the entire strata from well to well.

In carrying out the operations of extracting the sulphur from a mound equipped as indicated in the drawing, I regulate the specific gravity of the heating vehicle according to the position at which it is desired in the sulphur stratum. Thus if the zone B is being mined the heating liquid might be introduced through any of the wells shown. If introduced at A" the gravity of the heating liquid might be heavier than that found in the mine at B. However, the heating liquid may be introduced at C' or C" and, as the point of discharge from these wells is lower than B the specific gravity of the heating liquid should be regulated to be lighter than that of the cold mine water, so that it will seek the higher levels at B. My object is thus to determine the specific gravity of the ground water and thus regulate the density of the hot water to direct it to the level desired.

Obviously as the salt solution is pumped into the mine it will mingle with the ground water gradually increasing the density thereof, but by the observations constantly obtained I am enabled to vary the density of the solution accordingly, and by this means can control the flow of the solution being introduced so that it may be applied to the area where the deposits of sulphur are to be found before its melting heat has been dissipated.

The fact that the solution I contemplate using may be varied so that it is at all times of greater density when below 240° F. that the density of the adjacent ground water as determined by the observations is an important feature of my procedure.

From the foregoing it will be readily apparent that I may conduct my method consecutively in either zones A, B, C etc., or simultaneously or in any order, dependent upon the temperature and density of the ground water of that particular zone. If desired, the heated solution may be introduced in well B', whereas it rises and the melted sulphur may be taken from well B' and as this solution sinks a small introduction of solution into well C' will result in a material production of melted sulphur, due to the pre-heating it has obtained from the previous solution from well B'.

It is usual in a sulphur dome to have what is termed a bleed well from which the accumulation of ground water, or mixture of water and solution may flow. Obviously, I may use any one of the series of wells for this purpose, depending upon whether I desire to discharge the cold ground water as at C' or an accumulation of relatively warm fluid at A'. This may very well vary with the amount of sulphur remaining to be mined or the location thereof.

It is known that the use of a salt solution in sulphur mining is not new but the application and manipulation of the solution dependent upon the density and temperature of the ground water or contents of the mine is believed to be distinctly novel.

Having described my invention, what I claim as new and desire to protect by Letters Patent is:

1. A method of mining sulphur which comprises introducing into the mine a superheated solution having a density which is lighter at the time it is introduced than the density of the ground water present in the mine, but which upon cooling below the melting point of sulphur has a greater density than the ground water in the mine.

2. A method of mining sulphur which comprises introducing into the mine a superheated solution having a density which is lighter at the time it is introduced than the density of the ground water present in the mine, whereby it will rise relative to said ground water melting the upper strata of sulphur, but which upon cooling below the melting point of sulphur has a greater density than the ground water in the mine.

3. A method of mining sulphur which comprises introducing into the mine a superheated solution having a density which is lighter at the time it is introduced than the density of the ground water present in the mine, whereby it will rise relative to said ground water melting the upper strata of sulphur, but which upon cooling below the melting point of sulphur has a greater density than the ground water in the mine.

4. A method of mining sulphur which comprises introducing into the mine a superheated solution having a density which is lighter at the time it is introduced than the density of the ground water present in the mine, whereby it will rise relative to said ground water melting the upper strata of sulphur, but which upon cooling below the melting point of sulphur has a greater density than the ground water in the mine.

5. In the mining of sulphur by means of a heated fluid, the improvement which comprises introducing into the well a heated solution of fluid of such specific gravity when introduced as to displace the existing fluid contents of the strata by initially rising above the resident fluid and to subsequently
increase the specific gravity upon cooling so as to sink below the said resident fluid.

6. In the mining of sulphur by means of a heated fluid, the improvement which comprises introducing into the well a heated solution of fluid of such specific gravity as to displace the existing fluid contents of the strata by initially rising above the resident fluid and which upon cooling will have a greater specific gravity so as to subsequently sink below the said resident fluid, thus supplying a melting heat to the upper sulphur strata and pre-heating the lower sulphur strata.

7. In the mining of sulphur by means of a heated fluid, the improvement which comprises introducing into the well a heated solution of fluid which increases in specific gravity upon cooling and which is of such specific gravity as to displace the existing fluid contents of the strata by initially rising above the resident fluid and subsequently sinking below the said resident fluid, thus supplying a melting heat to the upper sulphur strata and pre-heating the lower sulphur strata, and subsequently introducing a heated solution of a different density to melt the pre-heated strata.

8. In the art of mining sulphur, the steps of drilling a plurality of wells to enter the sulphur bearing strata at different elevations, introducing a sulphur melting solution in some of said wells, observing the flow of such solution in the strata from other of said wells and altering the density of the solution subsequently introduced to control the flow thereof and cause it to make contact with the sulphur in the mine, and observing the subsequent flow.

9. The process of obtaining sulphur from the earth comprising drilling a plurality of wells to enter the sulphur strata at different elevations, introducing a heated sulphur melting solution into one or more of said wells, controlling the density of said solution to such an extent that it will rise above the ground water in the well so long as it retains a heat above 240° F. and will descend below the ground water when its temperature falls below 240° F.

10. A method of controlling the flow of a sulphur melting solution in sulphur mines, comprising altering the density of the solution to control the flow thereof with respect to the ground water in the well so that the solution will contact with the sulphur at any desired level, and periodically observing the flow of the solution.

11. A method of controlling the flow of a sulphur melting solution in sulphur mines, comprising altering the density of the solution to control the flow thereof with respect to the ground water in the well so that the solution will contact with the sulphur at any desired level.

12. A method of mining sulphur comprising heating a liquid above the melting point of sulphur and regulating its specific gravity relative to the ground water in the well, so that it will be directed to the desired level in the well.

In testimony whereof I hereunto affix my signature this 11th day of December, A. D. 1928.

BENJAMIN ANDREWS.