THE RESISTANT INTERSALT ROCK SEDIMENT LAYERS FORCED CONTROLLED DESTRUCTION TECHNOLOGY PRINCIPLES WHILE UNDERGROUND CAVERNS CONSTRUCTION BY THE SOLUTION MINING METHOD

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The technology proposed is relevant for the controlled, forced destruction of resistant intersalt sedimentary rock layers (RISRL), with a thickness up to on tenth of the maximum cavern span. It provides necessary conditions for cavern's development as a whole without the destruction of hydromechanical, heat mass transfer and physico-chemical process characteristics of the layers beneath the RISRL.

1. INTRODUCTION

RISRL's are usually present in salt along with frequently dispersed insoluble particles (DIP) lead to different complications and damages during cavern's development process and its operation. These complications can be avoided.

2. GEOLOGY

The presence of RISRL in rock salt deposits is usual for many salt fields in the world, for example in the USA /2/ , in Canada /3/ , in France /4/ , in Russia & CIS (IrkutskLena's, Near- Caspian, Near-Pripiat's, Near-Erevan's basins) and so on /5/. The RISRL's thickness varied in wide limits from centimetres to tens of meters.

The RISRL composition also varies, and mainly gypsoanhidrite, dense clays and claystones are prevalent. Russian rules /6/ require the study of the raw RISRLs mechanical & water-physical attributes when exploring for construction sites for underground storage's. But hitherto RISRLs attributes were inadequately studied. It is essential that RISRL composition materials are sediment rocks of the ancient evaporation basin and that these are essentially dry or dehydrated "in situ".

3. COMPLICATIONS

Experience with the construction of underground caverns in rock salt deposits around the world established that many thin RISRLs or those composed of weak rocks, for example, thin laid clays or gypsum lose most of their firmness when absorbing water. When the surface of these RISRLs laid bare by solution mining underneath reached a size of tens of square meters, these RISRLs unexpectedly collapsed without any serious technological complications, if the loss part of height well's open interval and accordingly maximum cavern's volume loss is not a problem.

But that is not true for unexpected and uncontrolled collapse of thicker RISRLs (about 1 m and more) composed of resistant rock, for example anhydrite or dolomite, that absorb rather little water. Such an event can lead to the jamming, bending, crumpling or even tearing (cutting) of the hanged well column in the developing cavern, rendering it inadmissible.

But if even if a collapse does not occur, RISRL can lead to other complications. The cavern wells are usually not vertical (as designed). If hanging column drops its shoe, which is inevitably located at the RISRL roof ledge, this could lead to longitudinal bend in the dropped column and in bad case to it crumpling or cutting. The tubular gap between hanging column and the RISRL (after column dropped to well's bottom) could be sealed by the DIP dropped from the upper well's part. That can lead to jamming and cutting while lifting the column. Finally when solution mining is carried out above and below a RISRL, connected through a narrow tubular gap, the cavern development will be more prolonged, i.e. the development beneath and above the RISRL will be separate and successive. To avoid these complications and damage to the hanging column it is necessary force a controlled destruction of the RISIBL.

4. THE RISRL'S DESTRUCTION LIMITS

Full RISRL destruction within the design limits of the cavern volume is usually impossible. Firstly, because of the large decrease in height of the well and the corresponding decrease in the maximum cavern volume. The volume of the disperse insoluble particles after crumbling is usually less then a factor 1.2-1.5 larger than the volume occupied "in silt". In contrast, the effective volume rock of the RISRL expands by a factor of two after destruction, dropping on the bottom of the well and forming a chaotic heap there. The porous space within the heap is about 50 % after natural selfcondensation. These figures are routinely encountered in the mining development practice and it confirmed by the experience of two underground caverns in Canada /3/, each about 150000 m^3 in size.. The roof one cavern was destroyed unexpectedly during the 5th and 7th year of operation, with gas pressure limits in cavern from about 40 bar to 200 bar. The thickness of the RISRL was 8.2 m and after destruction caverns bottom level rise was estimated to be more than 36.0 m and about half of useful cavern's volume was lost. In a similar cavern a roof layer 7.0 m thick was destroyed in the 14th year of exploitation and the bottom level rose by 12.2 m. Furthermore, the hanging (working) tube column was bent and damaged as a result. So the height of the bottom heap formed by rock from the destructed RISIRL was about twice of that of the RISRL itself, which greatly increased the loss in cavern volume. When the destructed area of the RISRL is small, the losses ni cavern volume will also be small. The destructed area of the RISRL must therefore be minimised. But on other hand that size must be large enough as to provide enough room for the free hanging column rise and lower through the RISRL without getting stuck, sealing and other complications in order not to obstruct movement of the solving water through the RISRL. The analysis of these conditions provides the minimum needed RISRL destruction size (Table 1).

Table 1

Well's deviation from vertical grad (angle)	Length from well's case shoe to RISRL's bottom, m 20	60	100
1.0	0.63	1.29	1.96
4.0	1.65	4.30	7.00

The data in table 1 are based on Russian rules/7/ that permit well's angle deviation from vertical at 1-4 degrees. Furthermore, the hanging column diameter is 300 mm (12"). The data in the lower row of the table are more realistic as these refer to the high limit of the well deviation. These dates account for the stiffness of the hanging column that does not permit it to hang strictly vertical in free cavern space to RISRLs roof. The width of the tubular gap at these conditions also provides the free DIP's particles movement through RISRL and so free hanging column rises without sealing. The destruction radius of the RISRL required by the second is more complex to calculate because needs a accurate hydromechanic analysis of the mixed (combined forced and natural) convection in volume within the limits of the complex form ,so this remains a subject of future studies. But for rough evaluations we can use data from industrial caverns /3/ and the analogy with the liquid flow in tubes metering with a narrowing arrangment /9/. The Russian rules /9/ require that the screen's open hole area must be approximately 20% of the tube area. So RISRL destruction radius must be more than 45% of the designed radius of the cavern on the level of the RISRL. This value is probably somewhat high. Experience shows /3/ the narrowing cavern N 5's span from 90.5 m to 30.5 m at its 4th development step does not obstruct its development to span more than 71.6m above the RISRL. In cavern N 4 the span narrowing from 63.4m to 19.0 m does not obstruct the design development of the upper part of the cavern. These data permit to believe that RISRL's destruction radius of more than 0.3 times the cavern design radius is roughly sufficient to development the cavern as a single unit. In that case the fulfilment of first of the mentioned conditions is also guaranteed. In this manner, the radius is about the same as usually selected sump radius at in the first step of the cavern's development by the solution mining method.

5. THE RISRL'S DESTRUCTION METHODS

The RISRL's controlled destruction task is mitigated. essentially by the fact, that it is composed of sediment rock, often actively absorbs water and brine, due to inner physic-chemical processes that change it structure and which usually result in partial loss of its firmness. This stimulates the

3. Decrease of the cavern brine level beneath the RISRL bottom level.
4. The decrease of the cavern inner gas/liquid. pressure to atmospheric pressure beneath the RISRL.
5. A waiting time to allow the salt overlaying the RISRL to provide, through creep and tension relaxation, conditions for overburden pressure strength.
6. Cyclic increase and decrease of the cavern gas pad pressure up to ten times the maximum admissible limits /3/.
7. And (in extreme cases) the use of hydraulic cracking on the level of the RISRL roof. This technology uses for the RISRL destruction a brine level decrease which is confirmed indirectly by data in table 2.

Table 2: Calculated RISRL self-destruction's radii in different conditions m

RISRL's environment	RISRL's thickness, m 0.2	0.4	1.0
Air at atmospheric pressure	13.22	20.8	30.6
Saturated brine	17.5	27.5	39.8

RISRL: claystone of 26100 kg/m3 density, the extension firmness 1,0 MPa

Th cavern gas pad pressure decrease provides transfer RISRL rock tension from thecompression area to the extension area because the firmness of the extending rock is about ten times less then the rock compression firmness. The use of cyclic tension to destruct rock is well known.

6. CONCLUSIONS

1. When rock salt thickness is limited and divided by RISRL it is necessary in some cases force a controlled destruction of the RISRL to avoid technological complications and reduction of the height of the well and the cavern volume.

2. The full destruction of the RISRL at the cavern design volume is usually not feasible, so the central part of the RISRL must be destructed only with a hole area about 0.1 to 0.2 times that of the designed cavern area at the level of the RISRL level. This is a subject for future studies.

3. The controlled RISRL destruction can be carried by the different mechanical, chemical, physico-chemical and combined methods.

4. Most preferable is the RISRL destruction by underworking through the combined action of the overlaid rock weight pressure whilst uplifting action of the brine and the decrease and increase of the cavern gas pad pressure stimulate the most destruction tensions within the RISRL.

REFERENCES

1. Ivanov Ail. & oth. Halogen formation // Moscow, publ." Nedra", 1972, 328 p.(Rus).
2. Evans L1, Istvan 1, McDonald D. The Effect of High Insoluble Content on the Development of Nature Gas Storage Caverns in the Bedded Salt Formation of West Texas. SN1R1 spring 1997 meeting papers, presented Cracow Poland, May 11-14 1997, 527 p.(pp. 96-106).
3. Crossley N.G. Sonar surveys used in gas-storage cavern analysis. // Oil & Gas Journal , 1998 v. 96, N 18, pp. 96-106.
4. Laguerie P., Durup G. Natural Gas Storage Cavities at Monosque, France. Papers of SMRI Fall Meeting 1994, presented Hannover Germany. Publ. by KBB-SMRI 685 p. (pp. 487-510,491,495,Fig.5,6).
5. Mazurov V.A. Underground Gas-Oil Storage in Rock Salt Sediments. Moscow, publ."Nedra",1982, 239 p.(Rus),
6. Instruction on exploration a development for oil, oil products, LPG & natural gas storage's design & building in rock salt.(IGR-PHS-78), Leningrad , publ. VNIGRI, 1978 , 45 p.(p.21 4.58) (Rum).
7. Underground Storage of Oil, Oil Products & Liquefied Gases. Design Rules. SNAP 2.11.85 , Moscow . publ. "Stroiizdat", 1986, 36 penthouse.
8. The Rules of Gases & Liquids Flow Metering by the Standard Narrowing Arrangment (RD 50-213-80 Moscow, publ. "Standartov', 1982, 3 320 p. (Rum).)