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# GRADE CONTROL IN JADUGUDA URANIUM MINE, JHARKHAND

by

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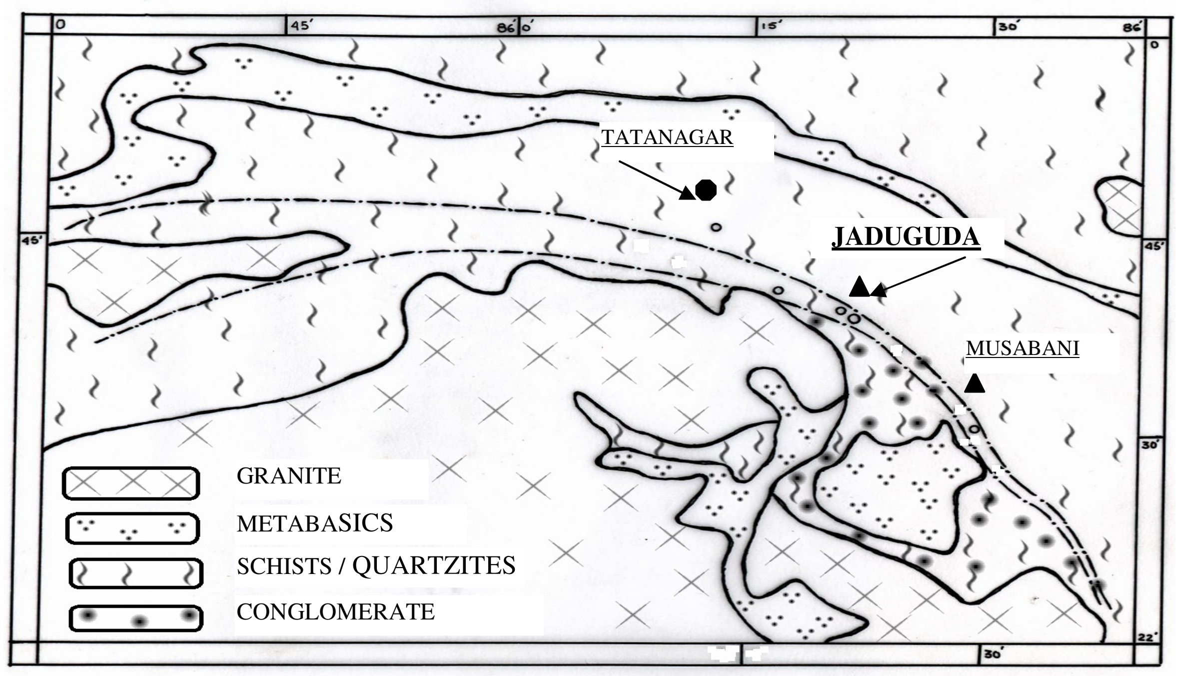
## ABSTRACT:

Jaduguda uranium Mine in the district of Singhbhum East, Jharkhand is in continuous operation since 1967 providing the basic raw material for the nuclear power programme of the country. The ore produced from the mine is treated in the metallurgical plant located close to the mine head. A series of innovative measures along with strict surveillance are adopted in the operation of the mine to supply the desired grade of ore to the plant. Uranium ore being a radioactive material, the radioactivity detection tools are extensively used for the purpose of grade control in the mine. The accuracy, rapidity and cost effectiveness of the system are the main features of the entire operation. The paper briefly describes all the steps in the system with a detail description of the tools used.

## 1. INTRODUCTION:

Jaduguda uranium deposit ( Lat. $22^0$ 39' : Long. $86^0$ 22') is located almost in the center of Singhbhum Thrust Belt(STB), Jharkhand (Fig. 1). The deposit was discovered in 1951 when intensive prospecting was carried out in STB for radioactive minerals. In 1967, Uranium Corporation of India Ltd (UCIL) was formed with an objective to mine and process uranium ore to meet the nuclear fuel requirement of the country. Since then, Jaduguda uranium mine is in continuous operation under UCIL. The ore produced from the mine are processed in the plant located close to the mine. The final product magnessium diuranate (called Yellow cake) is sent to Nuclear Fuel Complex at Hyderabad for nuclear grade fuel processing.

The low grade nature of ore available at Jaduguda calls for a very strict surveillance system in order to maintain the desired feed grade to the plant.




NOT TO SCALE

**GEOLOGICAL MAP OF SINGHBHUM THRUST BELT**

Mem. Geol. Surv . of India, Dunn & Day, 1942

**Fig. 1**

## 2. GEOLOGY OF JADUGUDA:

Uranium mineralisation at Jaduguda is in the pre-cambrian metasedimentary rocks of Singhbhum shear zone and are structurally controlled by strike-slip shears of Singhbhum orogeny. The host rocks are autoclastic conglomerate (formed by crushing, fracturing and brecciation) and quartz-chlorite-apatite-tourmaline-magnetite schist in which uranium bearing fine grained uraninite minerals occur as disseminated grains and micro-veinlets. The associated accessory minerals found along with uranium are the sulphide minerals of copper, nickel & molybdenum and magnetite. The ore is amenable to direct leaching by acid with high percentage of recovery. (Venkatraman etal 1971)

Mineable mineralisation at Jaduguda is confined to two principal lodes extending as veins following the general trend of the schistosity. Persistence of lodes is fairly uniform both along strike and dip with an average inclination of about $40^0$. The lodes are separated from each other by a distance of about 80m. Footwall and hangwall side rocks of both the uranium lodes are quite competent from geo-technical point of view.

## 3. MINING AT JADUGUDA:

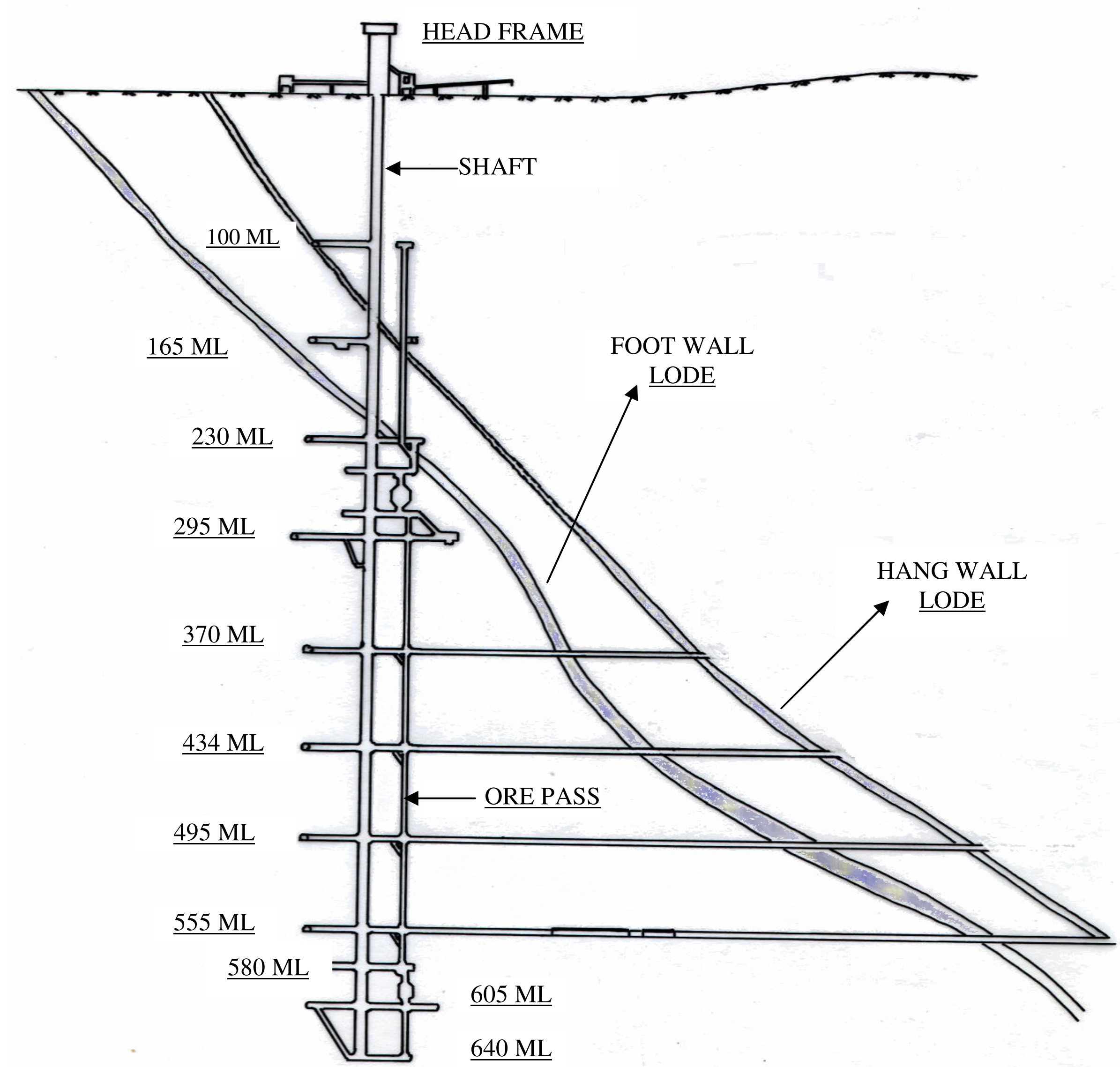
Jadugdua is an underground mine and the main entry to the mine is through a vertical circular lined shaft which has been sunk upto a depth of 640m. Levels are developed at every 65m vertical interval. In each level, x-cut is driven from the main shaft to the ore body. A common ore pass system is located near the shaft.

Horizontal cut-and-fill method of stoping is largely practiced in Jaduguda Mine. After the development of levels, width, grade and inclination of the orebody are established and mineable blocks are defined accordingly. Ore transfer raises, entry raises, footwall drifts etc are developed for each block prior to stoping. During the stoping, horizontal slices are taken and the broken ore are mechanically transferred to the foot-wall ore transfer raises using Load Haul Dump (LHD) equipment. At the bottom of these ore transfer raises, ore are loaded into 3.5 tonne capacity gran-by cars. These cars are hauled by diesel locomotives for automatic dumping into the ore pass. De-slimed mill tailings are used as back fill material in the stope.

Production by above means from all the levels are transported by gran-by cars and dumped into the respective grizzly connected to the ore pass. The ore in the ore pass gravitate down to 580ml(crushing station) where it is crushed to – 4” size by an underground jaw crusher. The crushed ore is then hoisted from 605ml (loading station) by a skip running in the main shaft. (Bhasin, 1989) (Fig.2).

## 4. IMPORTANCE OF GRADE:

Indian uranium deposits are of low grade. Amongst all the uranium occurrences presently being mined in the country, Jaduguda hosts the best mineralisatiom. Still, uranium content in ore of Jaduguda deposit is too low compared to many other uranium deposits of the world. In such low-grade deposits, a little drop in run-off-mine grade largely affects the cost of the final product. Hence, it becomes necessary to follow strict grade control techniques and measures to make the deposit economically sustainable.




**ORE BODY AND SCHEMATIC LAYOUT OF JADUGUDA MINE**

**Fig. 2**

## 5. TECHNIQUES OF GRADE ESTIMATION AT JADUGUDA:

In a conventional metal mine, grade of ore is normally determined by chemical analysis. But in case of uranium bearing rock, there is an alternative method to such time consuming procedure. Since the uranium ore contains naturally radioactive substances, qualitative and quantitative estimate of uranium can be made by the measurements of the intensity of their radiation. With suitable radiation detection systems, these determinations can be made possible ‘in-place’. Data regarding grade can be obtained at a very negligible cost in the shortest possible time and judiciously used on the spot.

The system makes use of the physical property of uranium called Radioactivity. Any radioactive substance while decaying, emit alpha (α), beta (β) and gamma (γ) rays. Uranium undergoes a series of transformations due to the emission of these rays, thereby producing isotopes of various elements called daughter products until a stable end product – lead ($Pb_{206}$) – is formed. These daughter products are also radioactive. Generally, all very old radioactive rocks having primary uranium also contain various daughter products in fixed proportion to their parent (uranium). In such a state - called ‘Secular Equilibrium’ - the intensity of any of the three above mentioned radiation is directly proportional to the parent element i.e. uranium. Since α and β rays are less penetrating, they are unsuitable for in-situ measurements by any detection system. But γ rays are highly penetrating lending themselves for use in detecting devices. This basic principle is utilised in designing the radioactive detection systems.

Apart from uranium, thorium is also another naturally occurring radioactive mineral. Uranium ore at Jaduguda is in the state of Secular Equilibrium and does not contain any thorium.

On the basis of above principles, two such radioactive detection systems are used in Jadugdua uranium mine for

a) Orebody delineation , b) Ore grade estimation and c) Grade control

GEIGER MULLER Counter – The assembly consists of a Geiger Muller tube detector filled with a mixture of argon and ethyl alcohol at a low pressure and enclosed in a moisture proof housing attached to a long conduit pipe. There is a wire at the center of the tube which acts as an anode and the co-axial housing cylinder acts as the cathode. The detector is connected to a composite count-rate meter with the provision for built-in high voltage power supply unit necessary for the detector and suitable electronic circuits to average out the detected signals.

The gamma radiation emitted by the volume of rock surrounding the detector are intercepted by the cathode and the resulting interaction produces ionization in the tube resulting electric signals. The converted electrical signals are read on the count rate meter which indicate the intensity of radiation in terms of current (Fig. 3).

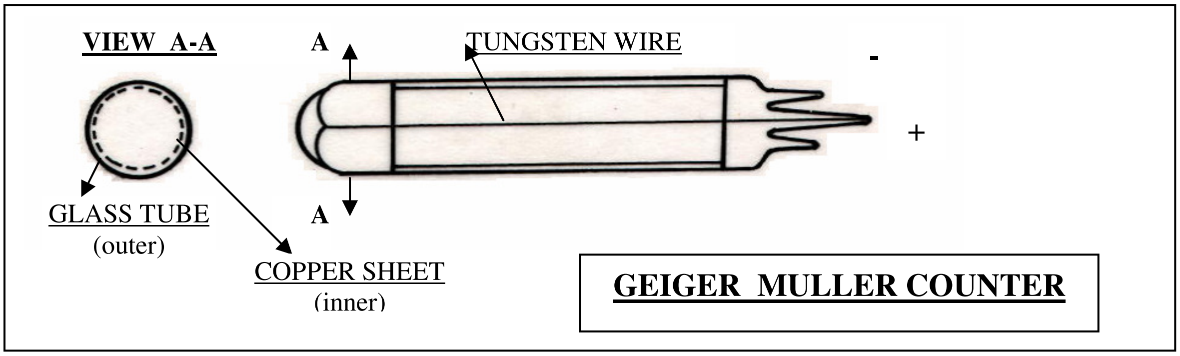



**Fig. 3.**

The whole detector assembly is fine tuned with suitable modifications to meet the rugged working conditions in underground atmosphere. Two such modified devices are

a) Shielded Probe – It is a semi-cyllindrical lead shield of 3cm thickness covering the tube from all sides except the floor through which the radiation from the rock are allowed to interact with the tube for detection. It is used for checking the excavation face, broken rock, stalk etc.

b) Borehole logging Probe – It is a moisture proof housing attached to a long conduit pipe with the Geiger tube inside. It is used in conjunction with a counting rate meter to determine the extend of mineralisation in drill holes at discreet depths.

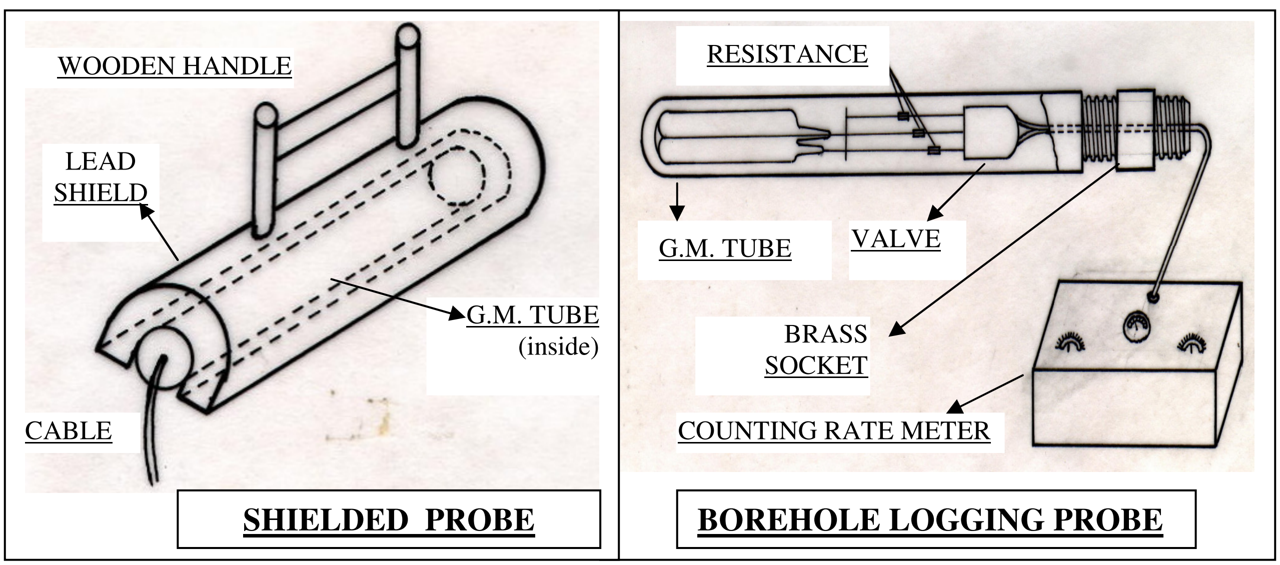



**Fig. 4.**

SCINTILLATION Counter – This consists of a thallium activated sodium iodide crystal and an electronic device called photo multiplier tube. Whenever gamma (γ) rays pass through this crystal, a part of the energy of the ray is absorbed in the crystal. This absorbed energy produces excitation in the crystal resulting in small specks of light called scintillations. These are picked by the photo multiplier tube, which in turn produces small electric signals. Since these signals are too small, they are amplified and shaped to equal amplitude pulses by means of electronic circuits. These signals can be counted correctly by scalar or can be converted to current measured by a counting rate meter (Fig. 5).

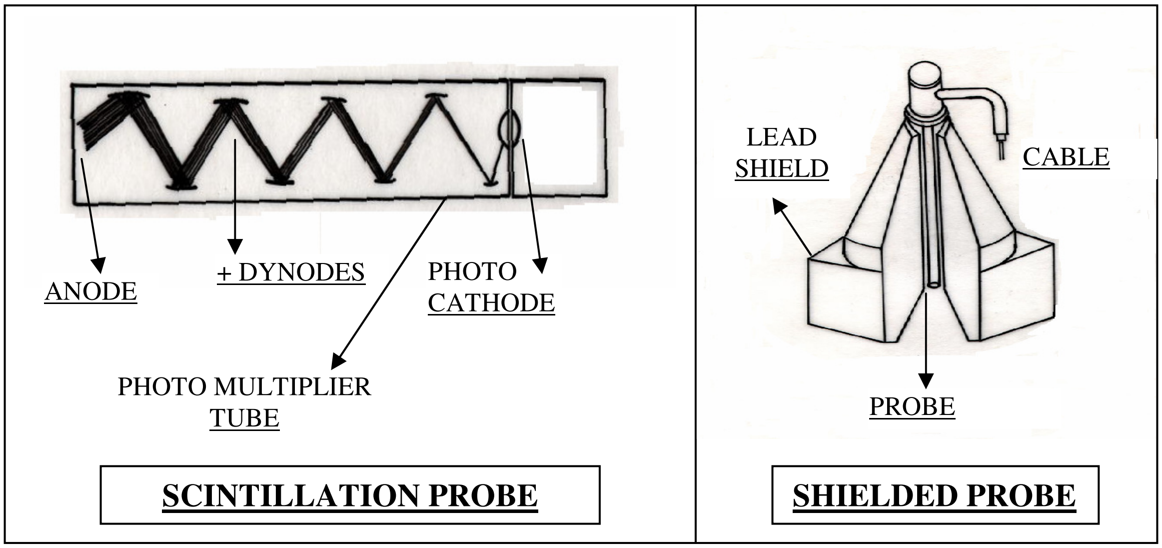


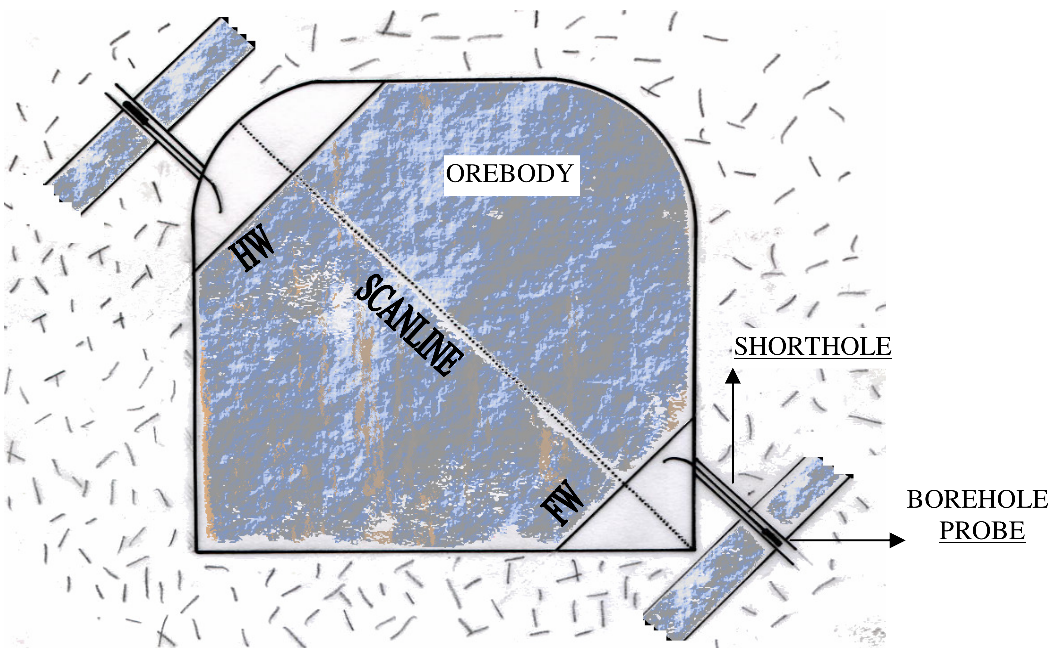

**Fig. 5.**

All these instruments are calibrated against known standards after a series of rigorous analysis over a large no. of samples of different uranium concentration and analysing the test results statistically. The measured intensities are expressed in terms of %$U_3O_8$.

## 6. PRACTICES OF GRADE CONTROL AT JADUGUDA MINE:

The basic philosophy of grade control at Jaduguda mine is the application of techniques / procedures to confine the excavation within the periphery of orebody. It is made possible by maintaining a strict surveillance on the orebody with the help of instruments during development of ore drive and stoping operations. Instantaneous assay of the mine cars through a state-of-art procedure developed at Jaduguda mine also help in maintaining a vigil on run-off mine grade and addressing the related problems, if any.

6.1. During the development of stage, all development point faces are systematically scanned after each blast with the help of Shielded Probe. In case of ore development, every blast face in the drive is scanned at 20cm interval starting from footwall corner of the drive face at right angle to the schistosity planes towards hangwall. Hangwall and footwall contacts are marked on the basis of cut-off grade. Considering the width and the trend of schistosity, center line is marked on the face and the roof. The line marked in the roof of the drive becomes the direction of hole drilling for next round of blast and the line marked on the face helps in deciding the drill hole positions. Sometimes when the orebody width becomes wider than the drive face, holes are drilled at right angle to the schistosity and logged with the help of Borehole logging Probe. Readings are taken at regular intervals and these information are used to estimate the grade and width of the orebody at the face. This helps in coursing the drive face as the face progresses with each blast (Fig. 6).




**MARKING OF ORE / WASTE CONTACT ON DEVELOPMENT FACE**

**Fig. 6.**

Thus, every care is taken to keep the ore development in ore zone only, eliminating the chance of missing the orebody unless any structural disturbance is encountered.

After the development of orebody, it is necessary to establish the grade and thickness of the orebody before starting the regular stoping. For this, channel sampling with the help of Shielded Probe is systematically done across the orebody at every 2m interval along ore drive and these data are synthesised –

a) to establish the grade and width of the orebody in each block
b) to prepare the assay plan of each level
c) to estimate the ore reserve

For the grade control point of view, the above information help –

a) to select the blocks to be mined
b) to choose the method or modify the method with an aim to reduce / eliminate waste development work
c) to choose the machinery in the stope that suits to the width of the orebody.

6.2. The role to control the grade during stoping is mainly aimed at keeping the excavation within the limits of already defined orebody. With every blast in each slice, hangwall and footwall contacts are marked by Shielded Probe as lines in the roof and face. Normally aluminum paint is used for marking these lines in order to have a better visibility. These demarcating lines help in directing the next course of blast and confining the excavations within the orebody thus reducing the dilution from side walls. This scanning is normally done before the next round of drilling. Sometimes the loose rock generated after the blast are also examined by Shielded Probe in the stope before they are shifted as ore. If the uranium content is found less than the desired values, the broken rock are disposed in the stope as filling material.

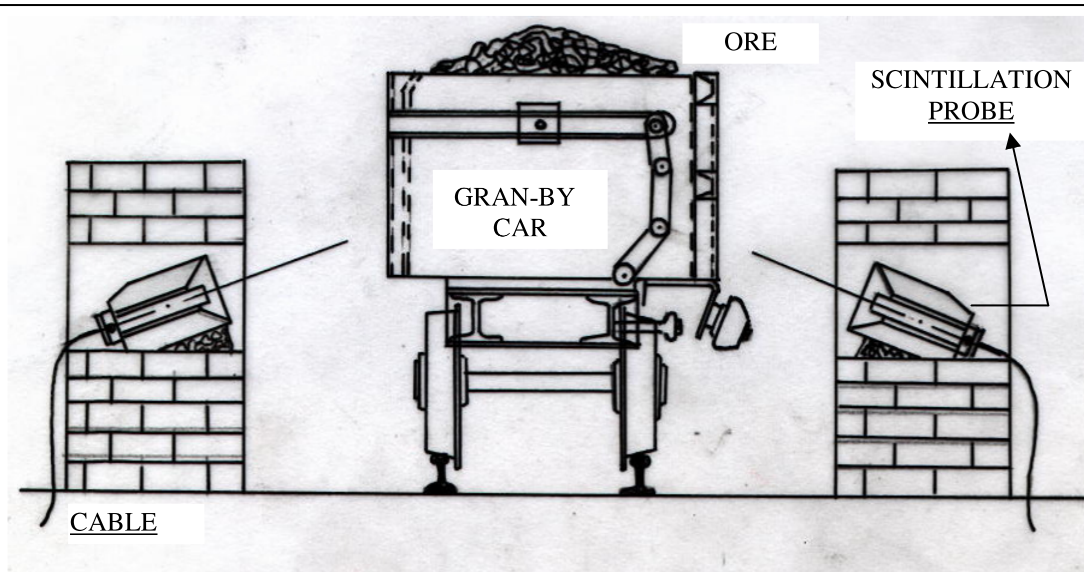
6.3. Broken rock (muck) generated by blasting in the stopes are brought to the tramming level through ore transfer raises and are transported to the ore pass. At this stage, it is necessary to make a quick estimation of the grade of ore. A very elaborate arrangement for this purpose has been done in the main tramming path in underground - called Bulk Ore Assaying - through which each car undergoes a thorough scanning.

The whole arrangement consists of two Scintillation detectors fixed in a particular geometry at an underground station. The gamma (γ) radiation coming from the ore contained in the tub / car are detected by these counters. The resulting signals after suitable amplification are received by count rate meter. Two level selectors are connected to the output of the counting rate meter. When the counting rate ( ore grade ) falls below or exceeds the desired grade (predetermined), the respective level selector trips the electromechanical relays causing the indicator light to glow. The detectors are provided with special collimated lead shields to cut off the radiation coming from adjoining cars. The count rate meter is calibrated in terms of

%$U_3O_8$. In actual practice, the operator positions the tub / car containing the ore symmetrically between the detectors and records the total counts for a period of 20 seconds. The background counts of the system also recorded for 20 seconds is deducted to give the net counts due to the source. The net counts when multiplied by the calibration factor provide the grade of the ore (in %U3O8) contained in the car. Finally the indicator light glows depending on the uranium content of the car (grade) and considering the above, the operator directs the path of the car. This enables to eliminate that part of ore, which is below the desired grade to reach the processing plant, thereby reducing the cost of hoisting and processing.

The grade and the number of cars (tonnage) thus recorded also help in computing the total production and grade of the level / mine at the end of the shift and day. Any fall in grade is immediately addressed at the muck generation point taking the reports from the operator. The record of the operator also helps in making a clear distinction between ore and waste sources avoiding any mix-up at generation points and subsequent transportation.

The underground station at which the bulk ore assaying system has been installed is called the Arch Room. This facility is available in each working level of the mine operating round the clock (Fig. 7).




**UNDERGROUND ARCH ROOM FOR BULK ASSAYING**

**Fig. 7.**

## 7. ADVANTAGES OF THE SYSTEM:

The above system of grade estimation is advantageous in many ways.

a) The physical process of grade determination is very cost effective compared to the conventional chemical analysis. The cost of accessories and consumables is practically nil.

b) A lot of time and effort is saved as there is no need for any elaborate arrangement of sample preparation as in the case of chemical analysis. It takes about 20 seconds to assay one source / point in this method.

c) The information is generated on the spot enabling implementation of quick follow-upial measures.

d) A large no. of data / information is generated (because of saving in cost and time) that brings in accuracy and precision in the whole grade control system and other related areas like reserve estimation, ore reserve status and mill recovery etc.

e) No human error is expected at any stage of operation bringing in high level of confidence in the workings. At no stage, any doubt is raised on the quality of information.

f) The rapidity and ready availability of information helps a lot in mine planning and exploration.

## 8. IMPROVEMENT OF THE SYSTEM:

The system of grade control designed at Jaduguda are also implemented in other mines of UCIL after necessary correction in calibration. However, the system is undergoing continuous technological up-gradations improving upon the efficiency, accuracy, adaptability to underground mining environment and automation etc. Presently, a series of modifications have been carried out in the bulk assaying system at the deepest level of Jaduguda mine with the introduction of microprocessor based automatic recording device.

The bulk assaying system at Narwapahar mine of UCIL has also undergone major up-gradation with the installation of microprocessor based grade determination. It is fully automated with the facility of level selection for three pre-defined grade ranges. The microprocessor based circuits are programmable with logical and mathematical functions required for grade estimation and subsequent computation. The radiation / pulses received from trucks (LPDTs) are converted to audio-visual signals differentiating the grade ranges.

## 9. **CONCLUSION**:

Though the grade estimation at Jaduguda mine is based on the physical measurement of gamma (γ) radiation, regular chemical analysis of samples are also done at the laboratory as a routine check. Periodic sampling and subsequent chemical analysis of the ore are carried out at the processing plant to confirm the grade of ore supplied by mine.

Indigenisation of the whole system is another hallmark of the entire grade control operation at Jaduguda mine. The design, maintenance and improvement of the system etc. are done departmentally. A great emphasis is always laid on the training of the operators on proper handling of the equipment in the field, recording procedure, interpretation and required remedial timely action etc.

Run-off-mine grade of ore is considered as the backbone for the survival of any mining enterprise. With ample emphasis on production, safety etc, sometimes the importance of grade takes the back seat. But the system of grade control at Jaduguda mine is so designed that it has the built-in capacity to affect the production and therefore, always remains side by side with the production. This system design has largely contributed towards the overall efficiency of the unit making Jaduguda Mine as one of most successful mining ventures of the country.

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