SEMIENPIRICAL METHOD FOR CALCULATING EQIAVALENT DOSE RATES OF NON-STANDARD OPERATIONS DURING TRANSPORTATION OF SNF IN DRY SHIELDED CANISTER

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For effective implementation of ALARA approach, one should correctly know the values of expected equivalent dose rates. Doses of the personnel who will carry out preparation of workplaces will depend on accuracy of such estimation as well as the doses received by the personnel, which will perform work.
In cases complicated for calculation, the most close to reality results can be received through application of so-called “semiempirical” methods of calculation. The algorithm of calculation is given below (Fig.1) in a schematic way.

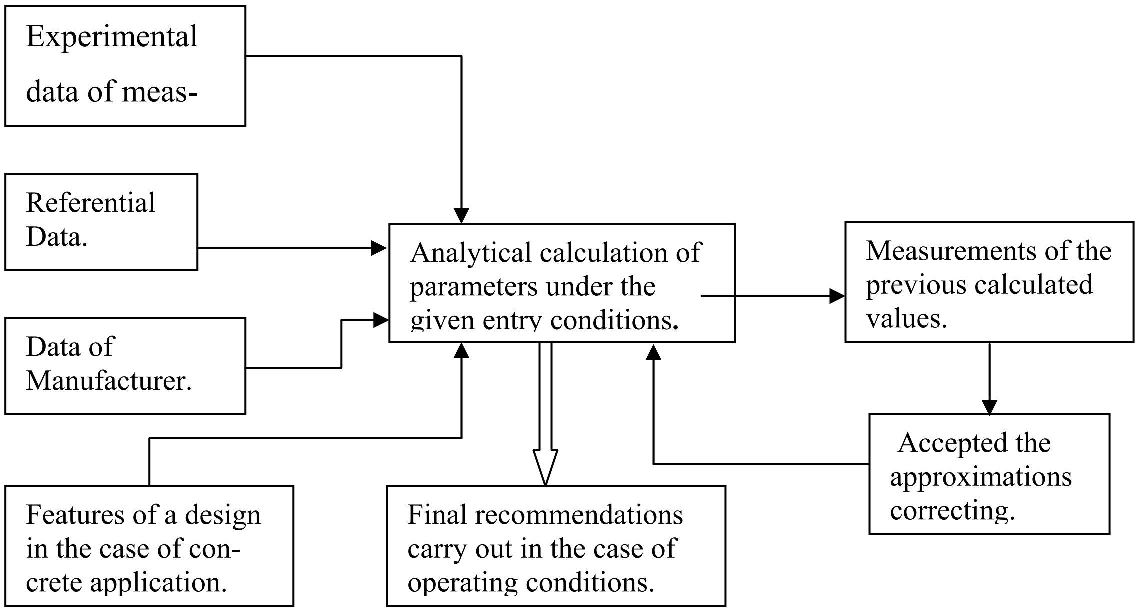


Fig.1

Calculation algorithm used the data of EDR measurements from the container loaded with a nominal SNF, the container design specific features, the container configuration for such usage, work performance procedure technique, and also tabulated and analytical formulas of calculating radiation protection. The subsequent comparison of the measured values of equivalent dose rate with precomputed dose rate has shown correctness of the calculation algorithm: the divergence did not exceed 3 per cent.
For procedure of (from spent nuclear fuel storage pool of Unit 2 to Unit 1) the spent nuclear fuel transportation in " FRAMATOME “ Company manufactured container, in case of loading the container with a non-standard (other, than the design) SNF, we carried out semiempirical calculation of expected equivalent dose rates. Those coordinates in areas potentially attended by the personnel who conduct work were selected (Fig.3).
Calculation of capacity of a doze from DSC in a radial direction was carried out by the following method:
- EDR at a distance of 1 m in a radial direction from DSC with SNF ten-year period of storage was measured.
---The relation of activity SNF with a period of storage 1 year and 3 years to activity SNF with a period of storage of 10 years was defined, using data from publications [1].
This factor was applied to an estimation of capacity of a EDR at a distance of 1 m in a radial direction from DSC with SNF 1 and 3-years periods of storage.

$$P_{\gamma,t} =(A_t/A_{10})^* P_{\gamma 10 \text{ year, measured.}}$$

Calculation of dose-rate (P□) in a cabin of the crane and on a workplace of the worker who is taking out water was carried out as follows:
---Effective energy of photons was accepted 1 Mev, according to the power spectrum SNF given in reference publication [1].

---Since dose-rate from the basis of the fuel can exceeds many times the dose-rate in a radial direction the source was accepted as a disk with measured, for SNF with 10-years time delay, dose-rate at a distance of 10 sm above the center.
---Multiplicity of easing differs from those at measurement of dose-rate since there is no cover fuel can, that results in decrease of easing in 25 times and to the appropriate increase of EDR also in 25 times.
---In case of moving SNF with a period of storage 1 year and 3 years were applied the appropriate factors of increase of EDR because of increase of activity SNF.
---The principle of the conservative approach was applied - was considered, that the burn-up of fuel 32 MW day / kg of uranium and the relation activities, is the greatest one noted in publication.
The formula, used for calculation of dose-rate is taken from [2];
The designations represented in figure 2; "Q" - is a dimensional constant.

$$P(h) = Q*\ln(\frac{H^2 + r^2 - R^2 + \sqrt{r^4 + 2*r^2\langle H^2 - R^2\rangle + \langle H^2 + R^2\rangle^2}}{2H^2}$$

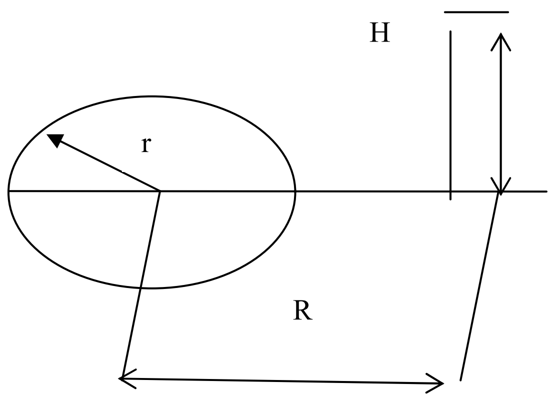


Fig.2

The estimation of radiation conditions near the DSC is carried out at the following initial data:
---Results of measurement EDR (mSv/h) the DSC with SNF 10-years endurance and burn-up of 32 MW day / kg of uranium.
---Time of operation of the DSC lifting and lowering makes (10+10 =20 minutes
---Time of transportation from unit 2 to unit 1 makes 20 minutes
---Time needed for partial water, discharge makes 10 minutes.
--- SNF reloading with endurance 1 year and 3 years is supposed.
---The distance from the top basis of the DSC up to the worker who is taking out water (worker *2), makes 1,5 m.
---The distance from a cabin of the crane up to the basis of DSC makes:
Height-6m; horizontal distance 2m and 12 m, accordingly at lifting, lowering and at transportation of the DSC.
---Thickness of protection lining of top basis DSC - steel 20 sm.
Calculation of EDR from the DSC (was carried out at full loading - 56 fuel assembly and storage SNF 1year and 3 year) and dozes on workplaces of the crane operator and the worker making partial water discharge.

Value of dose-rate makes:
At a distance of 1 m from a lateral surface of the fuel can:
1 year of storage SNF-10.9-6.48 mSv/h; (calculation)
3 years of storage SNF - 2.16-3.24 mSv/h; (calculation)
10years storages SNF - 0.72-1.08 mSv/h; (measurement)

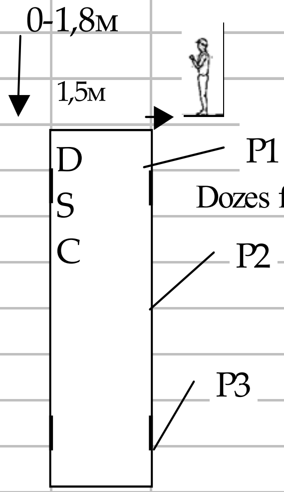
Dozes on workplaces for one operation movement:

	Cabin of the crane operator:	On all body of the worker (plums of water)
1 year of storage SNF:	0.215-0.1 (mSv); (calculation)	0.578 mSv; (calculation)
3 years of storage SNF:	0.64 - 0.032 (mSv); (calculation)	0.187 mSv; (calculation)

10years storages SNF: 0.011 - 0.0055(mSv); (measurement) 0.06 mSv; (measurement)
Smaller values of a doze in a cabin of the crane for a case of installation of lead protection of 13 mm. Results of calculations are resulted in the below-mentioned table:

h(m) of worker #1	Pg Ts=10	Crane R=2м;h=6м	Crane R=12м; h=6м	Ts=1 Pg	Ts=3 Pg	Ts=10 Pg	Ts=1 D	Ts=3 D	Ts=10 D
0,1	4,53			42,16	13,60	4,53	0,25	0,08	0,03
0,2	4,50	Pg; Ts=10	Pg; Ts=10	41,88	13,51	4,50	0,25	0,08	0,03
0,3	4,45	0,53	0,12	41,42	13,36	4,45	0,25	0,08	0,03
0,4	4,39	D; t=20	D;t=20	40,80	13,16	4,39	0,24	0,08	0,03
0,5	4,30	0,01	0,001	40,03	12,91	4,30	0,24	0,08	0,03
0,6	4,21	Pg; Ts=3	Pg; Ts=3	39,13	12,62	4,21	0,23	0,08	0,03
0,7	4,10	1,58	0,35	38,13	12,30	4,10	0,23	0,07	0,02
0,8	3,98	D; t=20	D; t=20	37,04	11,95	3,98	0,22	0,07	0,02
0,9	3,86	0,02	0,004	35,89	11,58	3,86	0,22	0,07	0,02
1	3,73	Pg; Ts=1	Pg; Ts=1	34,69	11,19	3,73	0,21	0,07	0,02
1,1	3,60	5,28	1,17	33,46	10,79	3,60	0,20	0,06	0,02
1,2	3,46	D; t=20	D ;t=20	32,22	10,39	3,46	0,19	0,06	0,02
1,3	3,33	0,06	0,014	30,98	9,99	3,33	0,19	0,06	0,02
1,4	3,20			29,75	9,60	3,20	0,18	0,06	0,02
1,5	3,07			28,54	9,21	3,07	0,17	0,06	0,02
1,6	2,94			27,35	8,82	2,94	0,16	0,05	0,02
1,7	2,82			26,20	8,45	2,82	0,16	0,05	0,02
1,8	2,70			25,09	8,09	2,70	0,15	0,05	0,02
mean value	3,73			34,71	11,20	3,73	0,21	0,07	0,02

Dose-rate at a distance of 1 m, depending on a storage time.



Ts=10 measured	0,72	1,08	1,08
Ts=3calculated	2,16	3,24	3,24
Ts=1 calculated	6,48	9,72	10,8

Dozes for operation of lifting & lowering: in the cabin of the crane

	The same at protection -13 mm Pb
Ts=10;D=0,008	D=0,04
Ts=3;D=0,023	D=0,012
Ts=1;D=0,077	D=0,039

An operating time of 10 minutes (taking out of water)

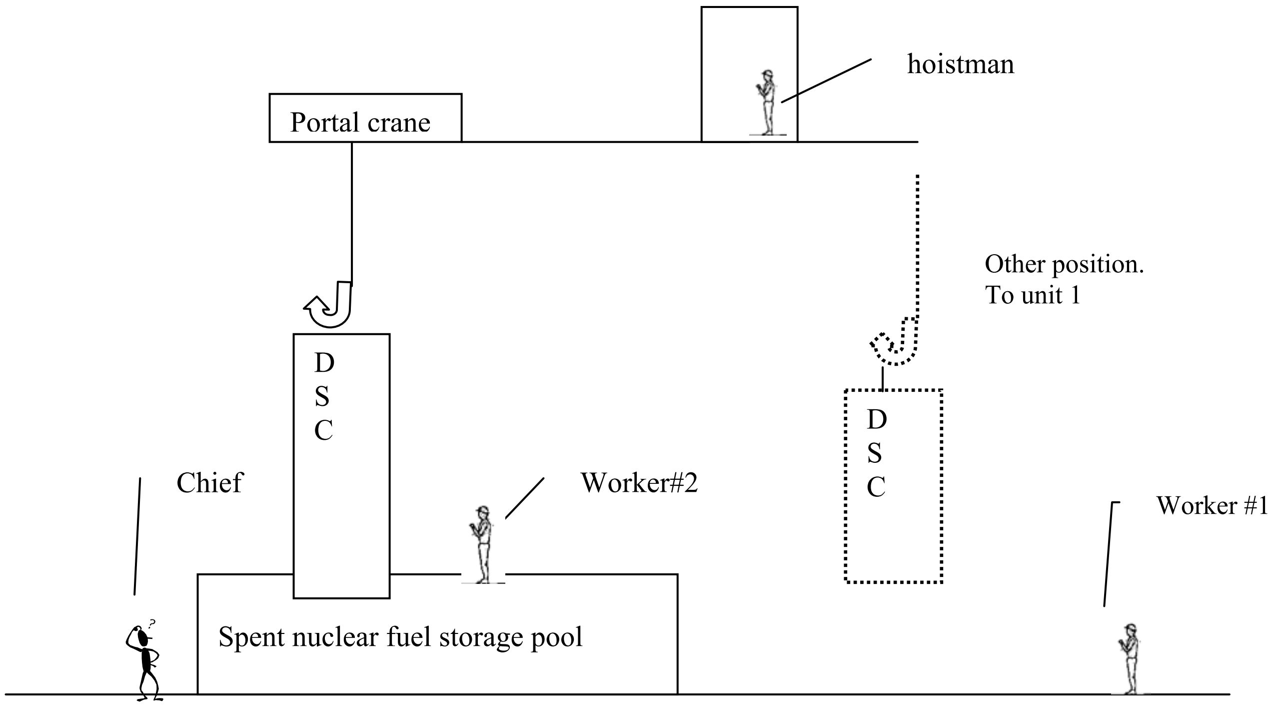
Designations and dimensions

Ts -storage time ; Pγ -dose-rate; D -dose

Tstorage=Ts (year) Pγ(mSv/h) D (mSv)

The shorthand notation existence in the text:
EDR – equivalent dose-rate;
DSC –Dry shielded canister;
SNF – spent nuclear fuel;

Conclusions:
Correct pre-computation of dose-rate and using of principle “ALARA” allowed us exclude inexpedient operations (plums of water) and considerably to reduce a collective doze (almost in 8 times).



Referents:

1.Колобашкин В.М. «Радиационные характеристики облученного ядерного топлива» М.1982
2.Кимель Л.Р. и др. «Защита от ионизирующих излучений» М.1972