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12. Health and Safety issues

12.1 Prognosis and Control of Beryllium Aerosols Concentration Under Normal Operations, Repairs, and Emergency Situations

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Prognosis of beryllium aerosols concentration concerns two main aspects:

1. Estimation of emission intensity
2. Assessment of ventilation efficiency

The first one is a matter of numerous reports been prepared in a framework of ITER EDA (Engineering Design Activity).
The second aspect is essential inasmuch as forming concentration of beryllium aerosols depends on ventilation efficiency vitally.
The main mechanisms of airborne beryllium contaminations are as follows:

- Sublimation and bulk condensation.
- Erosion and mechanical disintegration.
- Resuspeding from contaminated surfaces (secondary pollution).

Our report at BeWS-3 contains some theoretical and experimental data concerning above-mentioned mechanisms. Herewith, an attempt of enhancement and generalization of known and new results is presented.
Beryllium aerosols in existing TOKAMAKs are probably coming primarily from work in the torus. The disruption energy and burn-time are both low compared to ITER. Beryllium aerosols in ITER are thought to arise primarily from plasma wall interactions effects such as sputtering and disruptions. There is no single source of information that can provide a reliable basis for extrapolation to ITER beryllium aerosols production. Data from TOKAMAKs, plasma linear devices, high heated flux test facilities, and disruption simulators provide estimation of total quantity of generating of beryllium aerosols about 100 kg. But for all that, the uncertainty range is too high. The dust population has three sizes. The small size (plasma-vaporized in a sequence) could be ~0.1 μm. The mid-size particles are taken as 4 μm. The large size particles are taken as < 100μm. Known assumptions concerning the location of the dust give a supposition that only some of it is at "hot" locations due to various chemical reaction transients. For example, it is assumed 20% of beryllium aerosols are on the first wall (another 20% on the divertor). It is assumed with some uncertainty that 10% of metals is oxidized. So, for example, the inventory of unoxidized beryllium dust on the first wall would be 18 kg-Be, with 40 m^2/g effective surface area.
From technology point of view, remote aerosols handling operations may be classified as cleaning, collection, and removal. Cleaning operations remove retained aerosols, adhered aerosols, or re-deposited materials from the first wall and divertor target surfaces. Collection operations collect and/or transport dust within the vacuum vessel. Removal operations remove dust from the vacuum vessel. Cleaning operations include methods like CO_2, gas puffing, and thermal cycling, which loosen the aerosols from surfaces and allow it to fall to the bottom of the machine. Electrostatic is a collection and transport mechanism, which can move dust from beneath divertor pumping passages to an area where it can be readily removed. Vacuuming can either clean and collect aerosols from the first wall (if aerosols are loosely adhered) or collect and remove aerosols from the bottom of the machine (if the machine is open or perhaps has some valved opening). In principle, aerosols can be removed continuously during operation, periodically with minimal opening/perturbation of the vesssel ("partial" removal or cleaning such as the electrostatic method or flushing with CO_2/fluids to at minimum clean hot surfaces), or periodically during major interventions ("full" removal or cleaning). The more successful

continuous or "partial" removal/cleaning, the longer one can wait for "full" removal/cleaning and less potential for ratcheting the inventories. Remote maintenance operational scenarios and remote handling equipment/tools shall be designed to avoid the release and spread of contamination by use of transfer casks, double seal doors, and other means.
Maintenance access into the vessel is normally gained after an inspection campaign and lowering of the vessel wall temperatures to near ambient. Normally, a vessel cleaning process whereby a large fraction of releasable beryllium aerosols contained in inner vessel walls is removed precedes vessel entry. The vessel is then vented and purged.

The second aspect of the paper is aimed at a background of prognosis of beryllium aerosols concentration in real-world situations. Ventilation processes are architecture-dependent. Complicated geometry of the vessel renders impossible exact theoretical solutions. Experimental study is quite needed. Tracer-gas techniques are the only way of making many types of quantitative measurements of ventilation. These include infiltration, exfiltration, and air-exchange measurements; enclosure efficiency estimation, and characterization of spreading of pollutants. A very important aspect of tracer-gas measurements is that they can be made in functioning objects. This is especially valuable since it takes into account effects that aren't predictable theoretically more or less accurately. Three tracer-gas methods are possible for usage:

1. Concentration-decay
2. Constant emission
3. Constant-concentration

All three methods are based on a simplification of the continuity equation

$$V \cdot \frac{dC}{d\tau} = F(\tau) + q_V(\tau) \cdot C_{oa} - q_V(\tau) \cdot C(\tau) \qquad (1)$$

where:

V volume of air inside an enclosure, m^3;
C concentration of tracer-gas inside an enclosure, m^3/m^3;
τ time, h;
F introduction rate of tracer-gas into an enclosure, m^3/h;
C_{oa} concentration of tracer-gas in outside air, m^3/m^3;
q_V air-flow through an enclosure, m^3/h.

This can be written:

$$q_V(\tau) = \frac{F(\tau) - V \cdot \frac{dC}{d\tau}}{\left(C(\tau) - C_{oa}\right)} \qquad (2)$$

To find air-exchange rate, N, the airflow through the vessel is divided by effective volume of the vessel. The above-mentioned three main measurement methods for determining the airflow through a vessel are considered below. To sake a simplicity, in each case we assume that the outside air does not contain any of the used tracers.

Concentration-decay method

This is the most basic method of measuring air exchange rates and is used to obtain discrete air-exchange rates over short periods of time.
A small quantity of tracer-gas is thoroughly mixed into the vessel air. The source of gas is then removed and the decay in the concentration of tracer-gas in the vessel is measured over a period of time. To ensure that the tracer-gas concentration is the same at all points in a vessel at any particular time a big mixing fan is run throughout the measurement period. Provided that no tracer-gas is supplied to the vessel during the measurement period and the airflow through the vessel is constant, the concentration of tracer-gas is found to decay exponentially with time. By

plotting the natural logarithm of gas concentrations against time a straight line is obtained and the gradient of the line is the air-exchange rate in the vessel:

$$N = \frac{\ln C(0) - \ln C(\tau_1)}{\tau_1}, \quad h^{-1} \tag{3}$$

where:

$C(0)$ concentration at time = 0 (m^3/m^3);

$C(\tau_1)$ concentration at time = τ_1 (m^3/m^3);

τ_1 total measurement period (h)

If an approximately straight line is not obtained, then the vessel air cannot be considered well mixed and the results are thus not valid.

The only equipment needed for this measurement method is a gas monitor, a bottle of tracer-gas, and a mixing fan. This makes the method cheap and easy to perform.

Constant emission method

This method is used for long-term, continuous air-exchange rate measurements in single zones, or for measurement of the airflow through ventilation ducts.

When using the constant-emission method, tracer-gas is emitted at a constant rate for the duration of the measurement period. This means that provided both the air-exchange rate and the tracer-gas concentration in the zone are constant, the continuity equation reduces to:

$$N = \frac{F}{V \cdot C}, \quad h^{-1} \tag{4}$$

If either the air-exchange rate or the tracer-gas emission vary during a measurement period, then the general continuity equation has to be used to obtain the air-exchange rate. As with the concentration-decay method, the tracer concentration should be the same throughout the zone at any instant of time. The mixing needed to achieve this is done with fairly large mixing fans.

A flow meter is needed to measure the flow of tracer-gas emitted into the vessel. Since tracer-gas is emitted continuously into the zone throughout the measurement period, special attention should be paid to the cost and amount of tracer-gas used. Using a monitor that allows you to measure cheap tracer gases and/or allows very low concentrations to be detected and measured can help to keep this cost down.

Constant-concentration method

This method is used for continuous air-exchange rate measurements in one or more zones. It is particularly useful for conducting analyses in occupied buildings.

When using a constant-concentration measurement method, a gas monitor measures concentrations of tracer-gas in a zone. This information is then sent to a computer, which controls the amount of tracer-gas "dosed" into the zone in order to keep its concentration constant. A small fan is normally used to help mix the tracer with the vessel-air. In most cases, however, the air in each zone does not have to be perfectly mixed. Provided that the concentration of tracer-gas in the zone is constant over time, the continuity equation reduces to:

$$N(\tau) = \frac{F(\tau)}{V \cdot C}, \quad h^{-1} \tag{5}$$

The air-exchange rate is directly proportional to the tracer-gas emission rate required to keep the concentration constant.

This method offers two great advantages: not only can it be used to obtain an accurate long-term average air-change rate in situations where the air-exchange rate varies — for example, in occupied buildings; but it can also be used to document these variations in detail. As with the constant-emission method, tracer-gas costs may be an important consideration.

The constant-concentration method is also particularly well suited to the continuous determination of the infiltration and exfiltration of air into each individual vessel in a building.

One further useful quantitative parameter of ventilation is the age-of-air, which is a measure of the length of time it has been in the vessel. The "youngest" air is found where the outdoor air comes into the vessel, the "oldest" air may be found at any other point in the vessel. The age-of-air can be considered in two different ways: the local-mean age-of-air, and the vessel-average age-of-air.
Local-mean age-of-air is used if the ventilation of individual points. It is also used in the mapping of airflows through vessels. The big advantage of this method is that results apply to individual points within a vessel — areas of stagnant air can be located. Vessel-average age-of-air is a number, which quantifies the performance of a ventilation system. This number takes into account both the amount of ventilation air supplied to the vessel and the efficiency with which it is distributed around the vessel.
Vessel-average age-of-air is measured in the extract air-duct. This measurement is, however, not reliable in cases where a large proportion of air leaves the vessel by other means, for example, through random exfiltration.
The lowest possible vessel-average age-of-air occurs when there is perfect piston flow through that vessel. Piston flow is characterized by the fact that the oldest air is found at the extract air ducts.
If the air in the vessel is perfectly mixed then the vessel-average age-of-air will be double that of the case with piston flow. The age of air in the extract air duct is the same as that all other points in the vessel.
If there are areas of stagnant air in a vessel — due the short-circuiting of supply air — then the vessel-average age-of-air will be greater than the perfectly mixed case. The extract air being younger than the vessel-average age-of-air characterizes stagnant areas.
The advantages of piston flow (or displacement ventilation) and disadvantage of short-circuiting can be illustrated by considering a vessel in which both pollutants and heat are generated uniformly. With piston flow, extracted air will be hotter than and contain a higher concentration of pollutants than the average in the vessel. Conversely, with a less efficient short-circuiting pattern, extracted air will be both cooler, and contain a lower concentration of pollutants than the average in the vessel.
The efficiency with which the ventilation system exchanges the vessel air can be calculated by dividing the local-mean age-of-air in the extract by twice the vessel-average age-of-air.
The local-mean age-of-air in the extract is equal to the effective volume of the vessel divided by the airflow rate through it.
There are three tracer-gas methods for measuring the age of the air:

1. Pulsed injection
2. Concentration-growth
3. Concentration-decay

The equation, which allows age-of-air to be calculated, can be found in the table.

Tracer-gas measurement method	Measurement Equation	
	Local mean age-of-air $\overline{\tau_p}$ (Arbitrary measurement point)	Vessel-averaged age $\langle\overline{\tau}\rangle$ (Measured in exhaust)
Concentration decay method	$\dfrac{\int_0^\infty C(\tau)\cdot d\tau}{C(0)}$	$\dfrac{\int_0^\infty \tau\cdot C_{exh}(\tau)\cdot d\tau}{\int_0^\infty C_{exh}(\tau)\cdot d\tau}$
Concentration growth method	$\int_0^\infty\left(1-\dfrac{C(\tau)}{C(\infty)}\right)\cdot d\tau$	$\dfrac{\int_0^\infty \tau\cdot\left(1-\dfrac{C_{exh}(\tau)}{C(\infty)}\right)\cdot d\tau}{\int_0^\infty\left(1-\dfrac{C_{exh}(\tau)}{C(\infty)}\right)\cdot d\tau}$
Pulsed injection	$\dfrac{\int_0^\infty \tau\cdot C(\tau)\cdot d\tau}{\int_0^\infty C(\tau)\cdot d\tau}$	$\dfrac{1}{2}\cdot\dfrac{\int_0^\infty \tau^2\cdot C_{exh}(\tau)\cdot d\tau}{\int_0^\infty \tau\cdot C_{exh}(\tau)\cdot d\tau}$
where: $C(0)$ concentration at $\tau=0$ $C(\infty)$ concentration at $\tau=\infty$	$C_{exh}(\tau)$ concentration in exhaust $C(\tau)$ concentration at time τ	τ time

With the **pulsed injection method**, ventilation air entering the vessel is marked with pulses of tracer-gas at definite times and the tracer-gas concentration in the extract duct and at points of interest in the vessel monitored. The advantages of this method are that it is quick and comparatively little tracer-gas is used. The main disadvantage is that it is difficult to obtain rapid enough measurements of tracer-gas concentration in the vessel.

With the **tracer-gas concentration-growth method**, ventilation air is continuously marked with tracer-gas as it enters the vessel and the growth of tracer-gas concentration in the vessel studied. This method is useful in cases where a uniform concentration of tracer-gas throughout the vessel is difficult to achieve — for example, in very large vessels. A big disadvantage of the method is that only the distribution of supply-air provided by the ventilation system, which is measured.

Measurement with **tracer-gas concentration-decay** is the most popular age-of-air method. It is very similar to the air-exchange rate concentration-decay method except that no vessel-air mixing takes place after the tracer has first been perfectly mixed into the vessel air. With the tracer-gas concentration-decay method the air in the vessel is marked with tracer-gas and the decay of the gas concentration due to the infiltration of unmarked outdoor air into the vessel is studied. The local-mean age-of-air is simply the area under the concentration versus time curve. This method has the advantage that difficulties in marking all of the infiltration air are avoided. If the point at which the concentration change has been studied is in the extract air duct then the vessel-average age-of-air can be calculated. It is possible also to calculate the air-change rate for the vessel as a whole $(1/_{\text{local-mean age-of-air in extract}})$ and see whether or not there are areas of stagnant air in the vessel. By measuring the local-mean age-of-air at different points in vessel areas of stagnant air can be located.

Described above method and techniques of gas tracers provide definition a set of experimental parameters being used for prognosis of aerosol dissemination. Main mathematical expressions of ventilation indices are as follows:

Nominal time constant for the contaminant (τ_n^c)

This is also called the turnover time of the contaminant, or the transit time for the contaminant flow through the vessel. The nominal time constant for the contaminant is defined as the ratio between the equivalent volume of contaminant in the vessel and the contaminant injection rate.

$$\tau_n^c = \frac{V_c}{q} \tag{6}$$

where V_c is the equivalent volume of contaminant in the vessel (m^3), and q is the contaminant injection rate (m^3/s).

Note that the nominal time constant for the contaminant may also be expressed in terms of contaminant mass:

$$\tau_n^c = \frac{m}{\dot{m}} \tag{7}$$

The nominal time constant for the contaminant may also be defined as the average time it takes for the contaminant to flow from it source to the exact duct.

Contaminant removal effectiveness (ε^c)

Contaminant removal effectiveness is defined as the ratio between the steady state concentration of contaminant at the exhaust duct and the steady state mean concentration of the vessel.

$$\varepsilon^c = \frac{C_e(\infty)}{\langle C(\infty) \rangle} \tag{9}$$

Hence, it can be seen that:

$$\langle C(\infty) \rangle = \frac{V_c}{V} \tag{10}$$

Furthermore,

$$C_e(\infty) = \frac{q}{Q} \tag{11}$$

Substituting (10) and (11) into (9) gives:

$$\varepsilon^c = \left(\frac{q}{Q}\right) \cdot \left(\frac{V}{V_c}\right) = \left(\frac{V}{Q}\right) \cdot \left(\frac{q}{V_c}\right) \tag{12}$$

Substituting (6) into the above equation gives:

$$\varepsilon^c = \frac{\tau_n}{\tau_n^c} \tag{13}$$

where $\tau_n = \frac{V}{Q}$ is the nominal time constant for the ventilation air.

Hence, the contaminant removal effectiveness may also be defined as the ratio between the nominal time constant for the ventilation air and the nominal time constant for the contaminant.

Different types of ventilation give values of ε^c as follows:

Complete Mixing: $\varepsilon^c = 1$

Piston Flow: $\varepsilon^c \geq 1$

Short Circuiting: $0 \leq \varepsilon^c \leq 1$

Contaminant removal efficiency (η^c)

The contaminant removal efficiency is derived from the contaminant removal effectiveness.

$$\eta^c = \left(\frac{\varepsilon^c}{1 + \varepsilon^c}\right) \tag{14}$$

The values of η^c for different types of ventilation are thus:

Complete Mixing: $\eta^c = 0.5$

Piston Flow: $0.5 \leq \eta^c \leq 1$

Short Circuiting: $0 \leq \eta^c \leq 0.5$

Local air quality index (ε_p^c)

The local air quality index is defined as the ratio between the steady state concentration of contaminant in a point p of the vessel.

$$\varepsilon_p^c = \frac{C_e(\infty)}{C_p((\infty))} \tag{15}$$

Let note that the contaminant may be injected anywhere within the vessel.

Local purging flow rate (U_p)

Consider a small volume, δV, surrounding a point p. Assume that the air in this small volume is fully mixed, and that contaminant is injected at a constant rate, q_p. Let U_p be the effective flow rate at which contaminant is removed from the volume. This flow rate, which allows for contaminated air, which is recirculated back to δV, is called the local purging flow rate. If $C_p(\infty)$ is the equilibrium concentration within δV due to the injection rate q_p, then a contaminant balance on δV gives:

$$U_p = \frac{q_p}{C_p(\infty)} \tag{16}$$

If the total flow rate through the room is Q, and the injection rate q_p leads to a concentration $C_e(\infty)$in the exhaust duct, then $q_p = Q \cdot C_e(\infty)$ and U_p may also be written as:

$$U_p = \frac{C_e(\infty)}{C_p(\infty)} \cdot Q \tag{17}$$

Let note that because, in this case, $C_p(\infty)$ is the concentration due solely to contaminant injected in the volume δV, then $C_p(\infty)$ cannot be less than $C_e(\infty)$. Hence the maximum value of U_p is the fresh airflow rate Q. In the case of piston flow, U_p is equal to the actual flow through δV, and if in addition δV is an elemental plane perpendicular to the flow, then U_p is equal to Q.

Total dosage index (D_p)

The dosage index is the integral, over a convenient period of time, of the contaminant concentration at a point p. It corresponds to the area under the concentration curve.

$$D_p(\infty) = \int_0^{\tau} C_p(t) \cdot dt \tag{18}$$

When the integral is taken over all time, that is $\tau = \infty$, the resulting integral is called the total dosage index (or the total exposure index), D_p.

$$D_p = \int_0^{\infty} C_p(t) \cdot dt \tag{19}$$

Clearly, D_p may be obtained by numerical integration of the measured contaminant concentration curve. Alternatively, consider a small volume, δV. The total equivalent volume of contaminant, V_{cp}, leaving δV, regardless of the manner in which it is injected, must be:

$$V_{cp} = U_p \cdot \int_0^{\infty} C_p(t) \cdot dt = U_p \cdot D_p \tag{20}$$

Hence, substituting for U_p from (16):

$$D_p = V_{cp} \cdot \left(\frac{C_p(\infty)}{q_p} \right) \tag{21}$$

where $C_p(\infty)$ is the equilibrium concentration in δV due to a continuous contaminant injection rate q_p. Thus, if q_p and its corresponding $C_p(\infty)$ are known, then D_p is the total dosage index due to the release of a quantity V_{cp} of contaminant within δV. The equation may also be expressed in terms of contaminant mass:

$$D_p = m_p \cdot \left(\frac{C_p(\infty)}{\dot{m}_p} \right) \tag{22}$$

Where the dosage at point p is required due to contaminant release at some other point n, then, provided the fraction of contaminant released at n which reaches p is the same for short term release as for continuous release, equations (21) and (22) will still hold, that is:

$$D_{pn} = V_{cn} \cdot \left(\frac{C_p(\infty)}{q_n} \right) = m_n \cdot \left(\frac{C_p(\infty)}{\dot{m}_n} \right) \tag{23}$$

The dosage at p due to the release of the same contaminant at several different points may be found by summing the dosages due to each individual point.

Transfer index (T_{pn})

The transfer index, also called the index of exposure to contamination, is used for describing transport of contaminants between two points in a vessel. If an equivalent volume of contaminant (V_{cn}) is released suddenly at a point n in the vessel, and the concentration $C_p(t)$ is measured at a point p in the vessel, then the transfer index, T_{pn}, from point n to point p is defined by:

$$T_{pn} = \frac{\int_0^\infty C_p(t) \cdot dt}{V_{cn}} \tag{24}$$

By using the equations for the total dosage index, we may also express the transfer index as:

$$T_{pn} = \frac{D_{pn}}{V_{cn}} = \frac{C_p(\infty)}{q_n} \tag{25}$$

where $C_p(\infty)$ is the equilibrium concentration at p due to a continuous injection, q_n,..at n.

The equations may also be expressed in terms of contaminant mass:

$$T_{pn} = \frac{\int_0^\infty C_p(t) \cdot dt}{m_n} = \frac{D_{pn}}{m_n} = \frac{C_p(\infty)}{\dot{m}_n} \tag{26}$$

Relationship Between Indices

The indices ε_p^c, U_p, D_p and T_{pn} are inter-related, and may be combined in several ways. However, in doing this, it is necessary to specify the point at which contaminant is injected, especially when the local air quality index is included. Some useful equations are as follows.

1. Provided ε_p^c is the local air quality index due to contaminant injected at p, then

$$\varepsilon_p^c = \frac{U_p}{Q} = \left(\frac{U_p}{q_p} \right) \cdot C_e(\infty) \tag{27}$$

and

$$\varepsilon_p^c = \frac{V_{cp}}{Q \cdot D_p} = \left(\frac{V_{cp}}{q_p \cdot D_p} \right) \cdot C_e(\infty) \tag{28}$$

2. Provided ε_p^c is the local air quality index due to contaminant injected at n, then

$$\varepsilon_p^c = \frac{1}{Q \cdot T_{pn}} \tag{29}$$

Above introduced experimentally obtained data allow prognosis and decision-making support for control of beryllium aerosols concentration under normal operations (mostly stationary condition), repairs, and emergency situations (explicit dynamic condition).
A bulk of calculations presumes computerized processing and corresponding mapping which is convenient for perception and decision-making. Using electronic atlases put this into practice.
An electronic atlas as an automated special-purpose system provides for data manipulation and processing by using special algorithms with a result of automatic image construction as situation maps, which define the general picture and dynamics of the pollution under particular conditions.
The conceptual model of electronic atlases is determined by the behavior of experimentally received results, as well as by specific nature of practical tasks.
With regard to the peculiarities of experimental procedures with the use of gas tracers, the stored experimental data refer to conditions without taking into account Archimedean forces and aerosol particle sedimentation. This requires corresponding recalculation (should the need arise) on the basis of the given balance fall-down velocity or specific density of particular ingredients of pollutants. Furthermore, the stored experimental information mainly refers to stationary pollutions, which requires recalculation in dynamic conditions for pulse (delta-function) exposures or for intensities of pollutant entry (arbitrary in time), using Green functions on the principle of superposition. Besides, due to the conservative nature of gas tracers used in experimental studies the stored information doesn't take into account chemical activity of real pollutants that requires corresponding recalculations on the basis of physical and physicochemical properties of each ingredient and groups of ingredients with a result of formation of derivative products. Because of the conditions of absolute reflection of impurities from surrounding surfaces used in experiments the stored information does not take into account deposition and re-suspending of pollutants. Thus, the mentioned processes should be numerically taken into account in accordance with real operating conditions.

Electronic atlases are destined for the following main tasks:

- Visualization of the predicted circumstances (normal operations, repairs, and emergency situations).
- Interactive communication with the user for chousing scenarios (source type, released location, aerosol dispersion, etc.)
- Identification of highly hazardous zones integrally or according to some dangerous factors with regards of using regular or special means of individual protection.
- Tracing of the safest ways of the personnel evacuation and rescue teams moving in emergency situation.
- Generation of the network (cardinal points) of operative sanitary and hygienic inspection
- Estimation of probable consequences (damaging scale and degrees) of real and hypothetical emergencies, as concerned the attending and auxiliary personnel, as well the population of nearby areas.
- Expert estimation of the required bulks of medical aid, as well as attracted (in case of emergency) technical means and manpower to carry out works in a damage center.

Digital map descriptions for developing graphical actions are based on a laminated structure, which allows displaying both static and dynamic objects, changing their positions and configurations in the course of operation. Each graphic object is presented as a separate record connected to their content with corresponding references, libraries or catalogues by using special indexes.

The software used for prediction of chemical situations at the area of interest provides the following main functions:

- Transforming the source information stored in data bases in accordance with physically caused events and accompanying circumstances which characterize the conditions in specific situations determined by the user's inquiries (normal operations, repairs, and emergency situations).
- Providing the graphic dialogue in the course of interactive communication of the user with the system.
- Mapping and manipulating the map information (georelational processor functions).

The georelational processor providing displaying and manipulating the map information incorporates the following programming functions:

- Performing complex two-dimensional matrix conversions (map algebra).
- Calculating over objects in three-dimensional space.
- Defining point belonging to a field.
- Generating curves both on plane and in space.
- Performing Z-buffer conversions in the space of images (definition and removal of hidden lines).
- Constructing and modificating Voronoy's diagrams on plane.
- Performing Delone triangulalion.
- Calculating Hausdorf measures.
- Constructing splines.
- Approximating with Besier functions.
- Generating space-perspective images (prism style), anagliphs and 3-D maps.

To provide the effective work with map information and unification of the software under development when describing map base objects, vane lists with double links are used. These structures in comparison with standard graph list structures such as vane-node ones (lists of vanes with finite point coordinates) and node-vane ones (lists of nodes with incident vanes) offer more ample opportunities to analyze objects presentable as planar directed graphs.
The raster images are stored and processed in PCX format using standard facilities of working with PCX files. At the same time formats of raster images of TIFF type may be used provided that the latter could be converted into PCX formats. As mobile means of the informational exchange, formats of DBF-files are used.

The graphical interface working with electronic atlases provide for the following:

- Scrolling of a map through the display window in the world coordinate system.
- Scanning of mapping images parts with the aid of viewports.
- Changing of amounts of izolines, gradation and color spectrum.
- Map base manipulation and overlay of pictograms.
- Painting of fields.
- Mapping of coordinates in building axes or in Decart system.
- Receiving of additional reference information distributed in the area of interest.
- Cutting and pasting of raster and vector graphical images, application of texts.
- Organization of help and prompts in hypertext and ideographic modes.

The dialogue with the user is formed on the basis of positional menu combined with the crypto graphical system in accordance with main requirements and principles of object-oriented programming.