(1) Potable Water Reouirements.

(a) A sufficient amount of potable water will be required for drinking, food preparation, hand washing, and medical or first aid purposes. A minimum of 10 gallons of water per day per person should be provided for the EOC occupants plus an additional quantity to satisfy selected mechanical equipment requirements.

(b) The division between many of the items or functions that require potable or nonpotable water is arbitrary. Certainly it would be desirable that water for bathing, showers, and personnel decontamination be of potable quality, but nonpotable water could be used, if necessary. Drinking water and water used in food preparation must be potable. Water for personal hygiene should also be pure enough to drink. Water for first aid or medical purposes would, preferably, be sterile but should at least be pure enough to drink. Water for cooling systems should be as free of impurities as possible, to reduce deposits in the piping and on heat transfer surfaces: but it would not necessarily have to be of drinking quality. Water in closed circuit systems, such as chilled water cooling or hot water heating systems, should be treated and "softened" before going into the system. If only a single source of water is available, all the water supplied will be either potable or nonpotable. If it is nonpotable, equipment to purify it for drinking, food preparation, etc., will have to be provided in the EOC water system.

(2) Nonnotable Water Reouirements.

(a) It is not possible to establish specific criteria for a supply of nonpotable water since this would be completely dependent on the facilities and equipment in the EOC. In many EOC's there would be no requirement for nonpotable water since there would be no special facilities included in the EOC. In other EOC's, the requirements for nonpotable water could be very extensive.

(b) Some of the items or functions in the EOC that could possibly use nonpotable water without a deleterious effect are listed below:

(i) Baths and showers:

(ii) Cooling water for auxiliary power systems:

(iii) Mechanical cooling systems:

(iv) Firefighting equipment; and

(v) Waste disposal systems.

(c) With the large variation in possible requirements for nonpotable water, it is necessary to evaluate each **EOC** facility on an individual basis to determine the minimum supply which must be available.

(d) Water which is polluted or contaminated can be used for many of these applications, as long as the pollution is not such as to clog piping, valves or other parts of the system. Even in this case, the pollutants can often be removed by filtration. Water which is contaminated by radioactive fallout can also be used if precautions are taken to shield the equipment operators. Radioactive contaminated water should not, however, be used in sanitation systems since it would be inside the EOC in close proximity to the occupants.

(3) Sources of Water.

(8) Possible sources of water which might be considered are:

(i) Public water supply systems:

(ii) Wells:

(iii) Stored water: and

(iv) Trapped water in building systems.

(b) The most desirable source would be the normal water supply system since this would provide an almost unlimited supply of potable water. If the normal supply is a municipal system, it is necessary to make some evaluation of the probability of the system remaining in operation under fallout conditions. If it is assumed that there is no damage from blast or fire, the system should be operable. Whether or not it can remain in operation will depend on whether there is shelter for the operators and whether the plant can be operated from the shelter area. Power will be necessary to operate the Pumps, chlorinator and controls, so that emergency power equipment and fuel would be necessary to ensure continued operation.

(c) Many water supply systems already have emergency power installations to keep the system in operation, in case of power failure. Some have provided fallout protection for the operating personnel.-.- ,EOC's served by such systems quite possibly would have water available under fallout conditions. In some localities the water supply system is gravity operated and might well remain in operation even without power to operate the pumps.

(d) In a risk area which might be subject to the direct effects of a nuclear weapon, it is probable that the normal water supply would not remain in operation. A blast overpressure of 2 psi or greater would be sufficient to put most water supply systems out of service. Therefore, the public water supply system could not be considered an assured source of water for a blast-protected EOC.

(e) For most EOC's the best possibility for an assured source of water would be a well, if water can be obtained from a well of reasonable depth, in sufficient quantity and purity. Even if the water were not of potable quality, a treatment system could be provided adequate to supply the potable water requirements. If a treatment system is not feasible, it could be possible to purify the water by filtering, boiling or by the use of chemical disinfectants.

(f) Boiling water to purify it would probably not be suitable for use in an EOC because of the large amount of sensible and latent heat which would be released to the EOC atmosphere. It would also require a large supply of fuel.

(g) Chemical disinfectants which could be used would be liquid chlorine laundry bleach, chlorine tablets, tincture of iodine or iodine tablets. Most household laundry bleaches have instructions on the label for the amount to Use for water purification. Chlorine or iodine tablets may be purchased at most drug or sporting goods stores, with instructions for use.

(h) Neither boiling nor chemical disinfectants will remove radioactive contaminants from water. Filtering the water through a bed *of* sand or earth will remove most of the suspended particles, but will not remove the dissolved radioactive materials. It may be, however, that the dissolved radioactivity would be low enough to permit drinking the water. Removal of any large portion of the dissolved radioactivity would require rather sophisticated ion exchange treatment. It is, however;-,highly.improbable.that well water would be contaminated with radioactive fallout.

(i) If the cost of well and pump installation can be included in the available budget, a well should be installed. In fact, other less essential features of the design could be reduced or eliminated to make funds available for a well.

(j) If neither the normal water supply *nor a* well can be relied upon to provide the required water, it will probably be necessary to provide for storage of water in or near the building. This could be in the form of a storage tank in the water supply system. The main supply would feed into the tank with a check valve in the supply line, to prevent draining the tank back into the main in case of a loss in pressure in the main. Water would be distributed from the tank to the normal piping system of the building. In this manner, there would be a full tank of fresh water available at all times.

(k) For an EOC which is not in a risk area, the tank could be at the highest point in the building system. Under emergency conditions, the water could then drain by gravity flow for use in the EOC. It would be necessary to supply a vent or valve at the tank which could be opened to permit gravity flow.

(1) The water requirements for an EOC can be *great* enough *to require* a very large storage tank. Thus it would be necessary to investigate the structural feasibility of including the tank at the top of the normal system. If it is not structurally feasible and the EOC is in the basement of the building, the storage tank could be at ground level and still,provide gravity flow to the EOC. However, a booster pump

might be necessary to provide sufficient pressure for some applications.

(m) If the EOC is in a risk area, it would probably be best to install the tank below ground to help protect it from blast effects. However, water table levels and buoyancy effects must be taken into consideration for underground tanks. Normal water supply and distribution could still be made through the tank. With the underground tank, however, it would probably be necessary to install a pump to provide pressure for distribution under emergency conditions.

(n) When.the water.supply is. dependent on stored water, every effort must be made to conserve water usage in the EOC systems' design. Water cooling of the ventilation air would not be feasible and evaporative cooling would be questionable. Direct make-up cooling for an engine would not be possible. A water-cooled condenser in the refrigeration system would probably not be feasible. In general, more cooling would have to be done with air and less with water.

(o) In any building there is a significant amount of water trapped in the building systems: in water heaters, flush tanks, stand pipes and in the pipes. This water can be used if there is a way to drain it into the EOC space. This might require additional piping and valves and appropriate outlets in the EOC.

(p) It would be necessary to determine whether or not there would be sufficient trapped water in the building to justify the cost of additional plumbing work. It would also be necessary to determine that the water was usable. Rust inhibitors and antifreeze are often added to water in sprinkler systems and fire standpipes. These would render the water unusable for drinking purposes, although it still might be used as an engine'coolant.

(q) Water trapped in building plumbing systems normally would not provide enough water to meet the needs of an EOC, unless there were some unusual feature in the building which would result in a large quantity in the normal system. An indoor swimming pool, for example, would provide thousands of gallons of usable water. Such features would be rare in the type of building in which an EOC would be included. Trapped water could not, therefore, be depended upon as the primary source of supply. It could, however, provide a valuable supplement to the EOC water supply if it is usable and can be made available to the EOC.

(r) In a risk area, trapped water probably would not be available to a blast-protected EOC since blast effects on the aboveground portions of the building would probably cause numerous breaks in the piping systems. Any water in the systems would thus be lost.

j. Sanitation Guidelines. In any protective structure it is necessary to have a method of disposing of garbage, trash, and human waste. If flush toilets can be used, the capacity of the disposal system for human waste is not a critical problem. It can be assumed that the sewer system would have adequate capacity for whatever waste is produced. If, however, the sewer system cannot be used and/or there is not enough water available for flushing, other means of disposal would have to be used and the capacity required would have to be provided in the system's design.

(1) **Quantity of Waste.**

(a) There is considerable variation in the amount of waste production in an EOC, ranging from 0.12 gallons per person per day to as high as 0.45 gallons per person per day. These variations are probably due to different methods of measuring the amount of waste, whether or not the waste includes garbage and/or trash as well as human waste, whether wasted water is included, variations in diet and water intake and different levels of effective temperature. As a consequence, it is very difficult to determine a reasonable basis for planning the required capacity of a sanitation system for EOC use.

(b) The ratio of waste production to water intake is greater under winter conditions of low effective temperature than it is at high effective temperature. Under conditions of high effective temperature, a greater portion of the water intake is rejected as perspiration. At low effective temperatures, thermal balance of the body is achieved without activating the sweating mechanism: and water balance is maintained by rejecting the water as urine.

(c) In the summer time the ratio of waste production to water intake appears to be in the range of about

0.6, while in the winter it may be 0.7 to 0.75. In an air-conditioned EOC, it might be expected that the ratio would be closer to winter conditions than summer and a ratio of 0.7 might be appropriate. Thus, if the water intake is, say, two quarts per day, the liquid waste production would be about 1.4 quarts or 0.35 gallons per person per day. To this should be added some allowance for solid matter in the waste. Thus, a suggested minimum criterion would be a total of 0.5 gallons per person per day for human waste. Three quarts to one gallon per person per day would be preferable.

(d) If the human waste disposal system involves storage, in one way or another, the capacity must allow for an initial charge of disinfectant solution plus such additional disinfectant agents as may be required over the period of use.

(e) Liquid wastes other than human waste, such as used dishwater, may also be disposed of in the same system. The total capacity of the system would have to provide for this waste also.

(2) Plumbing Fixture Requirements. Suggested plumbing fixture allocations are shown in figure I-2.

(3) Waste Storaae.

(a) During normal operations, garbage and trash are usually placed in containers for collection by municipal or private trash collection services. Under emergency conditions, however, normal collection services would be suspended and garbage and trash would have to be stored for future disposal. Depending on the size of the staff, a trash compactor may be suitable.

(b) A storage space for waste containers should be provided in the layout of the EOC. This space should be physically closed off from the occupied spaces and from food storage and preparation areas. Ventilation air should exhaust through this storage area and normally would not be recirculated. Ventilation air for toilet areas would also be exhausted without recirculation. If the layout is favorable, it would be possible to exhaust air from the toilet areas through the waste storage room to the outside. Exhaust air from the waste storage area should not, however, flow through the toilet area or any other occupied space, or space which might be occupied, because of the danger of bacterial contamination.

FIGURE I-2

Plumbing Fixture Recommendations

For Protective Shelters

Type of Shelter	Wash Basins	Water Closets or Chemical Toilets	Urinals
Mass Personnel			
100 occupants	4	4	2
450 occupants	8	8	3
Command			
100 occupants	5	5	2
450 occupants	12	10	4
First Aid			
100 occupants	4	6	4
450 occupants	15	12	10

Since most EOC's separate sleeping quarters and restrooms for male and female personnel, the number and type of fixtures would be allocated according to the expected staffing of the EOC.

(c) If it should become necessary to recirculate air from the waste storage areas or toilet areas, such, as during "buttoned-up" operation,_ it would be necessary to pass the air through very high efficiency particulate filters to remove organisms and, preferably, through activated charcoal filters to remove odors before it is recirculated.

(4) **Waste Disposal.** Waste disposal systems for liquid and human wastes which might be considered for use would include municipal sewerage systems, septic tanks, sanitary vaults, chemical toilets, and storage systems.

(a) Reliance on municipal sewerage systems must be evaluated for each specific project. If the EOC is located at a high elevation and flow to the treatment or disposal facility is entirely by gravity, there is a reasonable possibility that, under fallout conditions, the sewer could at least carry off the effluent from the shelter, even if it bypasses the treatment plant. Even in a blast area, the sewer may be able to accept the waste from the shelter although flow to the treatment plant would be questionable.

(b) Use of flush-type facilities requires about 25 gallons of water per person per day. This might be reduced somewhat by not flushing the toilets every time they are used. Even if sufficient water for normal flushing is not available, existing toilets may be used to dispose of liquid or semi-liquid waste by forcing the waste with small amounts of flushing water through the traps using a plumber's plunger or similar device. Nonpotable water from sources other than the EOC water supply might be used for flushing by pouring it into the toilet. For example, used dishwater might be disposed of by using it to flush the toilets.

(c) As an emergency measure, toilet fixtures could be removed so that waste could be deposited directly into the sewer pipe.

(d) In all cases, it would be necessary that the sewer lines be at a lower level than the disposal outlet. In a basement EOC this might not necessarily be the case and waste would have to be pumped into the sewers. This would require the installation of pumps, the power and fuel to operate them and water to carry the sewage.

(e) Septic tanks offer some possibilities for waste disposal. However, they require relatively large areas for drainfields and a water supply to carry the sewage. For a below ground EOC, the sewage would probably have to be pumped to the septic tank. In addition, many local codes prohibit installation or use of septic tanks.

(f) One method of providing sanitation facilities at relatively low cost is the privy tank or vault. The vault may be of poured concrete under the floor or steel tanks may be used. This system avoids any need for handling the waste and is simple to use. A tank or vault capacity of about 250 gallons should be provided for each toilet seat connected to the tank. An ejector pump can be used to empty the tank after the emergency period is over, so that it can be used again. The effluent can be disposed. of by truck or into a septic tank or sewer system.

(g) The vent to the outside is for the removal of sewage gases. The decomposition of fats, carbohydrates and protein produce gases which include 65 to 80 percent by volume of methane, hydrogen and hydrogen sulphide, the remainder being carbon dioxide, nitrogen and oxygen. Such gases, in addition to having objectionable odors and possibly being toxic, can become violently explosive in mixtures of one part gas to five to ten parts of air.

(h) Control of odors from the privy tank can be achieved by chemical treatment. The chemicals which have been found most effective for the treatment of human wastes collected in open containers are:

(i) Cupric sulfate, sodium bisulfate, and mineral oil;

(ii) Saponified cresylic acids and mineral oil:

(iii) Boric acid, sodium perborate, and mineral oil.

(i) All three of these combinations give about the same degree of odor control 'and will reduce odor to a level which is not objectionable. The mineral oil in these combinations is intended to cover both liquids and solids to aid in odor control. The combinations with mineral oil have been found to be much more effective -in this respect than the same combinations without the oil.

(j) Although all three combinations give about equal odor control, it has been found that No. 1 has a more effective **bacteriocidal** action than the other two.

(k) Chemical toilets are readily available on the commercial market since they are produced for use in recreational vehicles, boats and for camping. However, these are generally small in size with a capacity of only about 6 gallons. Thus it would require about one unit per person to meet the requirements for an EOC. The space required would make them unfeasible and the cost might better be applied to the installation of a more satisfactory method of waste disposal.

(1) Storage of human waste in containers for later disposal is possible, but is not recommended. It should be considered for use only if no better method is possible.

(m) The decomposition of waste in a closed drum could cause a pressure build-up sufficient to rupture the polyethylene liner. Such an accident could contaminate food and water supplies, as well as expose the occupants to disease-bearing organisms. Immersion of the waste in liquid would tend to reduce the generation of gas and control odor production, but this would require additional available water in the shelter as well as decrease the waste capacity of the containers. Filled waste containers should be stored outside the shelter if possible, so that contamination from a possible accident could be minimized.

(n) Mixing food **scraps** with human waste would tend to increase the production of gases and odors. Therefore, food scraps should be stored in plastic bags and stored for later disposal. Each day's scraps should be placed in a separate container to avoid inoculating the new scraps with bacteria from the older, decomposed scraps. Highly absorbent waste such as diapers and sanitary napkins should be stored separately since they would otherwise reduce the effectiveness of chemical bacteria and odor control.

k. Shock Mounting When structural systems and equipment are subjected to the ground motion generated by a nuclear detonation **or** from seismic activity, the response of the system is a function of the masses and rigidities of resistance elements. In order to avoid damage, EOC equipment should be ruggedly mounted and shock isolated where necessary.

Shock sensitive equipment should be securely anchored, bolted, clamped, and braced. Shock sensitive equipment should also be mounted on shock isolators. Flexible connections should be introduced into piping (simple rubber hosing with clamps may be adequate). Piping may also need additional tie-downs. Slack should be provided in electrical cables. Desks, bookcases, and file cabinets should be securely fastened to the wall or floor. All loose and unnecessary items should be stored so that they cannot become dangerous projectiles. Shock spectra should be included in the structural specifications to allow suppliers to design a shock isolation system for their equipment, if required. Eguipment tie downs and shock mounts should be designed by an *engineer* knowledgeable in shock mounting and vibration isolation.

1. Decontamination.

(1) Due to the arrival of personnel who may be contaminated with chemical, biological, or other agents, a decontamination chamber should be provided. The room should be equipped with a high pressure shower, separate drain outlet, whisk brooms, clothing, and other necessary paraphernalia to help remove the contaminants. In addition, some type of gamma radiation detection equipment should be available. For personnel who are required to leave the EOC during the emergency period, throw away paper clothing, including shoe coverings should be stored.

(2) Information concerning decontaminating the surrounding terrain and the roof of the EOC to reduce the effect of fallout gamma radiation, may be found in the FEMA publication entitled Decontamination Considerations - TR-71.

m. Blast Valves.

(1) The Importance of Blast Valves. Although some mechanical and electrical equipment, such as engines, can withstand considerable blast pressures, the air handling equipment such as ductwork, dampers, filters, fans, etc., will be severely distorted at very low blast overpressures. Blast valves are used in the ventilation systems to prevent damaging pressure impulses from passing through the air intake and exhaust openings. These closure devices are placed in the intake and exhaust ducts and are normally open to allow air flow. The shock wave from a nuclear detonation is of fairly long duration and in effect builds up a reservoir of high

pressure at the outside of air openings. If there are no blast valves, a pressure impulse will pass through the openings. The amount of energy in the impulse is limited by the size of the opening. When the pressure impulse passes directly into the ductwork or filter chamber of the ventilation system, the ductwork will limit the space available for expansion and the wave shape inside the ductwork will approach the wave shape of the shock wave outside the structure. The overpressures, which probably will be present there, can easily damage the air handling system.

(a) When a blast valve, actuated by the blast wave, closes, the shock.-front and part of the shock wave are separated from the flow. The portion passing through the valve no longer represents a fully developed flow, but only an immediate pressure pulse. This pressure pulse has a high initial pressure which must be attenuated by an expansion chamber. In the expansion chamber, or plenum, the shock wave outruns its source of energy and the shock wave itself will cause little or no damage. If the air were not stopped by the blast valve, it would continue to flow through the opening as long as there is a difference in pressure between the interior and exterior of the building. The air travels at a much slower velocity than the shock wave, but will still cause damage.

(b) Because of air flow through the valve opening, it would be desirable to close the valve, either manually or with a sensor, prior to the arrival of the shock wave. If the valve is to be closed by the pressure wave itself, an expansion plenum would be required to attenuate the by-passed pressure impulse.

(c) It has been stated that the air handling system must be protected against high overpressures. Particulate filters can tolerate over-pressures up to about 3.0 psi. Prefilters can withstand higher pressures when properly mounted and when wire mesh is used for additional support.

(d) Tests have shown that the intakes and exhaust systems of diesel engines have a capability of withstanding overpressures higher than those the average EOC is designed to resist. Therefore, this equipment does not need to operate behind blast valves.

(e) The effectiveness of any blast closure device can be measured in terms of how much damage would result if the blast valve were not provided and how this damage would affect the operational capabilities of the EOC.

(2) Evaluating Blast Valves The operating capabilities of commercially available blast valves range from an overpressure of 25 psi to well over 500 psi, with varying closure times. The following criteria *outline the major items* to be considered when evaluating the design of blast valves.

(a) Overnressure Protection The valve selected must limit the blast overpressure to'a level that will not damage shelter occupants or equipment (air filter tolerance to a rapid pressure rise is approximately 3 psi). Human tolerance is above this pressure.

(b) Negative-Phase Protectiqn The valve must also limit the negative phase of the overpessure pulse (underpressure or vacuum phase reaches a maximum of 4 psi below ambient pressure) to a level that will not damage the equipment. The latching mechanism must prevent flutter or chatter.

(c) Loow-Pressure Drop In order to reduce power requirements and operating costs in the ventilation system, the pressure drop at the rated air flow through the valve should not exceed one inch of water.

(d) Closure. Two basic valve closure systems are available, one actuated by the blast wave itself, the other by an electrical signal from a sensing device. In each case, the valves *are* normally open, allowing air to flow inward and outward. In, the blast actuated system, the pressure wave generated by the nuclear explosion impinges directly on the valve head, effecting closure. The valve should actuate at the lowest blast that would *cause* damage inside the building. Sensor actuation is achieved by a device positioned some distance from the air intake where it senses either thermal or gamma radiation or the pressure wave generated by the nuclear burst and transmits a signal back to a built-in control system which automatically closes the valve. The thermal and gamma radiation sensors are located fairly close to the closure device since radiation travels considerably faster than the pressure wave and the time differential can be used to effect valve closure. The pressure type sensor is placed some distance away to enable signal transmittal and valve closing before, arrival of the pressure wave.

(e) Reliabilitv. The blast valve should be completely reliable under all the conditions within the design parameter. Capability of reopening after closure, accomplished either automatically or manually, is mandatory. Provision for reopening against an obstructing force or object is a design requirement.

(f) Repeated Attacks. The valve should have the capability of repeated operation at the design overpressure, including effects of reflection and impact.

(g) Maintenance. The valve should require only minimum maintenance between operations. An installed valve should not require that personnel expose themselves to a dangerous environment when performing valve maintenance or service after each operation. Parts should either be made of corrosion-resistant materials or be treated to inhibit corrosion.

(h) Thermal Resistance. Components of a blast valve system should be capable of continuous operation after exposure to the thermal radiation incident to the system's rated over-pressure. Positioning of temperature-affected components within the system is an important factor.

(i) Shock Resistance. Neither the air over-pressures nor the ground shock should prevent the valve from operating properly.

(j) **Environmental** Adaotabilitv. The valve should give satisfactory performance within a temperature variation ranging from 25*o.F below and above the minimum and maximum of record for the specific area. The design should provide environmental protection against birds, insects, debris, air-borne fragments and inclement weather, including accumulation of ice, snow and sleet. In cases where the valve is exposed to corrosive gases (exhaust or otherwise), it should be fabricated from materials that will not be subject to deterioration due to the corrosive action of the gases.

(3) Activatina Blast Valves.

(a) Blast valves that must be operated manually must be closed during the warning period preceding an attack, or a person must be stationed to close them when the flash of a nuclear detonation is seen. This person would have 3 to 4 seconds to close the valve and take cover. Both methods have obvious disadvantages, although manually operated valves would be less expensive than other types.

(b) Blast valves may also be closed by the pressure of the blast wave. This provides the advantage of automatic closing; but @'blow-by" of pressure before the valve closes completely may require an expansion plenum following the valve to attenuate the passed pressure.

(c) A system using sensors to detect a nuclear detonation will provide a time differential that can be used to effect valve closure. In order for the blast valve to be closed when the blast wave arrives, it must take longer for the blast wave to travel from the sensor to the facility than for the blast valve to close.

(d) Sensors are classified as optical, pressure, electromagnetic, thermal, seismic, or gamma ray depending on the actuating medium. Some of the characteristics of each type are discussed in the following paragraphs.

(i) Optical. There are three basic types of optical sensor systems: the single-pulse system, which responds to a high-in-tensity signal with a very short rise time; the double-pulse system, which responds to the double-pulse light signal that is characteristic of nuclear explosions: and the amplitude system, which responds to high-intensity signals. Double-pulse systems have been developed with varying degrees of success. A number of single-pulse and amplitude systems have been developed, but these systems in general are unreliable because they are susceptible to false signals such as weather conditions and manmade noise. However, a single-pulse detector has been combined with an amplitude detector to increase the range and reliability of the system. Adverse weather conditions, such as fog and dust, can seriously reduce the effective range of an optical sensor system. However, with favorable weather conditions, the detection range is adequate to protect against any desired overpressure level. The repeated-burst reliability of any given system depends on the way in which the sensor is mounted and how it is connected to the valve-actuation mechanism. Proper system design can make the repeated-burst reliability high, and can also reduce the problem of false signals caused by lightning and other phenomena. Attention must also be given to the problem of optical sensors being "blinded" by dust and debris. In some situations, the time required for the sensor system to produce a warning signal is a critical factor. These systems have minimum warning times in the range of 5 to 700 milliseconds (msec). The field of vision of the sensor may also be important. Some systems "see" only the horizon (full 360 degrees), whereas others see the full visible hemisphere of the sky. Full hemispherical coverage may be necessary to provide protection against high-altitude bursts at relatively short ranges.

(ii) Overpressure. The over- pressure sensor system utilizes a ring of sensors around the facility at a distance great enough to give the necessary warning time. Sensitivity of the sensors is such that a pressure pulse of 1.0 psi or less will trigger the system, thereby limiting overpressure to a level that will not damage the equipment. Systems of this type are unaffected by weather conditions. With proper design, the single-blast reliability can be close to perfect. Repeated-blast reliability depends on the survivability of the transducers and the connections between the transducers and the actuation system of the blast closure valve.

(iii) Electromagnetic Pulse (EMP). There are two basic types of EMP detection systems: those which give a warning whenever the EMP signal exceeds a certain amplitude, and those which examine the wave form of EMP and discriminate against false signals. The sensitivity of EMP sensors is not affected by weather conditions, and manmade noise is not usually a problem. However, these sensors may be triggered by lightning, because lightning can produce an EMP signal very similar to the one produced by a nuclear explosion. System sensitivity is adequate to protect a facility at any overpressure level. With proper design, the system will give -excellent repeated-blast protection.

(iv) Thermal Radiation A thermal radiation sensor responds to the infrared light wave associated with heat sources. This sensor cannot be triggered by either lightning or vehicle headlights.

(v) Seismic. A seismic sensor system responds to the seismic disturbances resulting from a nuclear explosion. Seismic sensor systems are usually amplitude-type device6 which are triggered by accelerations that exceed a certain minimum magnitude. It is possible for false signals to result from strong-motion earthquakes only when the threshold triggering level is less than about 0.5 gravity (g). Other properties of the seismic sensor systems are similar to those of the overpressure sensor systems.

(vi) Gamma Raqiation. Systems using gamma-radiation sensors are usually amplitude-type device6 that trigger when the radiation exceed6 a certain level. Low frequency change6 are filtered out to prevent triggering from the fallout of a distant nuclear explosion. Gamma radiation is not significantly attenuated by weather conditions. However, false triggering may be caused by cosmic ray Showers. This problem is eliminated by reducing the sensitivity of the system, which also decreases the maximum detection range to a point where protection is not reliable at the low overpressure regions. Systems of this type are easily hardened (that is, their ability to withstand nuclear attack is increased), and they provide coverage over the full visible hemisphere within detection range. Repeated-burst reliability is good.

(vii) Combined. Combination of the above-mentioned sensor systems can be used to improve the triggering probability for a single burst and to reduce the possibility of false alarms. TWO combined Systems that have been developed are: an Optical-gamma radiation-overpressure system that trigger6 on a signal from any one of the sensors; an Optical-EMP system that trigger6 on a signal from either sensor. It is evident that the cost of blast closure device6 actuated by remote sensors will be greater than for blast-actuated valves or manually operated valves. Such installations will also be more complicated and the additional components and circuitry will require more exercising and maintenance.

n. Blast Doors (or Closures). One of the more critical element6 of an entrance way system is the blast door which is designed to seal off the EOC from the effects of the blast wave. The blast door may also provide some additional radiation shielding, depending upon the mass of its construction. It is a complex structural-mechanical problem which should be part of the initial EOC system planning. The size, strength,and location of the blast door will influence the design parameter6 concerning the entrance way system as weil as the EOC proper.

(1) Design Considerations. In planning, prior to the actual design of the door itself, consideration must be given to the size of the EOC to be served, the attack warning time and the rate of traffic flow through the entrance way system. Federal requirements and/or local building codes may specify the size of the opening to be covered by the door. The location and orientation of the door to radiation and overpressure provide a variety of design constraints to be met.

(2) Input Data for Desian of EOC Doors. There are many solutions to a final design for a blast door, and any particular solution depends upon the input data.

(a) The door may be in a horizontal plane, a vertical plane or an inclined plane. The horizontal door at the ground surface has the advantage that it is subjected to only the peak overpressure from surface bursts; but it has the disadvantage of having to be larger than other door types in order to admit equal traffic flows. The vertical door is probably the most common for many reasons. However, it may have to sustain a high reflected pressure for most locations. The pressure loading for the inclined door would generally be intermediate between the vertical or horizontal door loadings.

(b) Door types may also be classified as to the manner in which they open. Doors may be sliding or rolling, hinged on one side at any one of its four edges, or hinged on both sides on various edges.

(c) Sliding doors have the advantage that they are stored out of the way of the traffic flow parallel to a wall surface or into a recessed opening when they are in the open position. Debris may work into the recessed opening, making operation of the doors difficult; and, usually, sealing of the door in a closed position is a more difficult problem.

(d) A major decision in hinged doors involves the direction of opening. Since the major traffic flow is into the EOC itself, safety rules would prescribe that the door swing into it. However, for closing and sealing purposes, it may be easier to solve these problems by having the door swing outward from the EOC. To prevent the door from obstructing the inflow of traffic, it is suggested that a recess be built into the corridor wall or ceiling so that the door is not projecting into the corridor. Typical entryway designs have utilized both types of doors, opening inwardly and outwardly: and the attendant problems in either case have been solved economically.

(e) On hinged doors, provision must be made for the relief of the hinges from the blast loads. This can be a difficult problem to solve. It is desirable to have the load on the blast door itself transferred uniformly to the supporting jamb. This condition will relieve the hinges of the load and also help to ensure an airtight seal.

(f) In the design of the door itself, a variety of materials have been utilized. Doors have been constructed of solid timber, hollow and solid plywood, cellular steel plate, solid steel plate, structural steel sections, reinforced-concrete, and prestressed concrete. The door surface configuration may be a flat slab or a rounded or domed surface. Rounded surfaces may be built-up steel plate sections, producing either a compression arch or a tension arch--depending on the direction of the arch normal to the blast wave.

(g) In the structural design of the blast door, it should be determined as to whether elastic deflection only is permitted or whether elasto-plastic deflection can be tolerated. If plastic deformation is permitted, a careful investigation should be made to ensure that jamming of the door is prevented under such deflections.

(h) The design should be examined with regard to the rebound under the negative pressure phase. Methods for manual latching of the door from the inside to maintain the pressure seal during the negative phase or for any required buttoned-up time should be considered.

(i) A special problem exists when elevator service is provided in the EOC. The elevator shaft may have to be structurally closed at the EOC level. Otherwise, a blast-resistant wall surrounding the elevator, plus a blast-resistant door for access must be provided.

0. Piping. When piping systems are designed for dual-use EOC's, the criteria for sizing, construction, and insulation will be essentially the same as for conventional practice. Such installations must conform to applicable codes. However, some consideration should be given to conservation of

energy and heat in the design, within the limits of code requirements. The design for a single-purpose EOC may be able to effect some economies in sizing, construction, and insulation, but attention must be given to the problem of severe corrosion resulting from intermittent use and long periods of standby. During normal operation, in a dual-use EOC, circulation of fluids in the piping systems would be achieved by water main pressure in some circuits and by circulating pumps in other circuits. The circulating pump motors would be operated on utility power. Thus, the power required to operate the systems would not be a problem except for the desirability of reducing operating costs. Under emergency conditions the power to operate the systems must be provided by the emergency generator which would supply power for the circulating pump motors and for, probably, a well pump which would provide pressure for those systems normally pressurized by the water main. The emergency generator would be selected for starting other loads and might well have excess running capacity which could be used for starting and operating the fluid pumps. The piping could then be sized to obtain the combination of pump and piping which would give the lowest overall cost.

(1) Insulation Reuuirements.

(a) In dual-use EOC's, insulation of the piping will follow conventional practice. Insulation is required to conserve heat, to prevent objectionable dripping from cold pipes and to prevent possible injury to personnel coming in contact with hot pipes.

(b) If pipe insulation is inadequate, some dripping from cold pipes may occur. In machine rooms or other service areas, this may not be objectionable; but care must be taken that the dripping does not create a hazard, such as dripping over electrical switch-gear. Dripping pipes in storage areas could result in damage to stored supplies and equipment and, in passageways, could cause slippery floors.

(c) In an EOC, dripping pipes in the occupied spaces would be highly undesirable, since it could result in wetting important papers and records. It would also be a distraction to the operating personnel. Thus piping should probably be insulated according to conventional practice even in a single purpose EOC.

(d) It is possible to combine the insulation with color coding of the pipes. In any event it would be desirable that the piping be coded and identified. The American Standards Association (ASA) has approved a scheme for identification of piping according to the nature of the contents. The basic colors and classifications are:

Red	fire-protection equipment
Yellow or orange	dangerous materials
Green	safe materials
Bright blue	protective materials
Deep purple	extra valuable materials

(e) The colors for safe materials, in addition to green, can be white, black, gray, or aluminum. Safe materials would include compressed air, cold **water,** and steam under vacuum. Dangerous materials are combustible gases and oils, hot water, and steam above atmospheric pressure.

(f) The entire length of the piping can be painted the main classification color or color bands can be painted on the pipes at intervals. In addition to the color code, the actual contents of the pipe can be indicated by a legend of standard size, giving the name of the contents in full or abbreviated form. Arrows are often added to show the direction of flow. The legends should be placed on the color bands.

(g) The color bands and legends should be placed at intervals throughout the piping system, preferably adjacent to valves and fittings to ensure ready recognition during operation, maintenance, or emergencies.

(h) It would also be desirable to post operating instructions and cautions at each valve and control, especially if sequential operation of the controls is critical. These instructions should be mounted and covered to prevent deterioration or defacement, and should **be** securely attached in a conspicuous location adjacent to the control so that they cannot be removed.

(2) **Maintenance of Piping Systems.**

(a) In a single-purpose EOC the use of the piping is intermittent and corrosion can be quite severe. In a dual-use facility some systems may be operated only under emergency conditions and, therefore, be subject to the same corrosion problems.

(b) Such systems should be operated at periodic intervals during the standby period to prevent accumulation of sludge and other materials which may tend to clog when the system is placed in operation. In this type of system, it is recommended that strainers be included to prevent malfunction of pumps, valves, and heat exchange equipment.

(c) Since it will be necessary to exercise the emergency engine-generator at intervals, it would be logical to operate the piping system at the same time.

(d) Between operating tests of systems which operate intermittently, it is recommended that they be secured in a filled condition and that water treatment chemicals be added during the circulating periods.

(e) The possibility should be considered that the system should be drained annually and refilled with fresh water and chemicals.

(f) Coils, valves and tanks should be cleaned annually to assure that the systems are in operable condition. When well water is used, special care should be given to the cleaning of the well water side of heat transfer apparatus.

p. Supplies The EOC, irrespective of size, and the number of people assigned for management, will require substantial quantities of material for equipment maintenance and personnel sustenance. Some type of storage area will have to be provided for all supplies. The overall requirement on an item by item basis will probably vary from one segment of the country to another.

(1) Mechanical Equipment. The manufacturers of the mechanical equipment should furnish a listing of all parts required for normal maintenance and a supplemental list of parts which may have to be replaced after a few years of operation. In addition, the manufacturer should be required to furnish data as to how long spare parts will be available. Based on these data and recommendations from the A/E designing the EOC, a determination should be made as to what items will be stored in the EOC and the quantity.

(2) Communications Equipment. The manufacturer should assess the fragility of the component parts of communication equipment and advise on its ability to withstand a specified ground shock or overpressure. Again, the stock level of spare parts to be maintained within the EOC will be furnished by the A/E, based on information furnished by the manufacturer.

(3) Food Stocks. Storage space for food for personnel assigned to operate the EOC during a crisis, should be provided. The space should accommodate food for at least 14 days.

(4) Water Storaue. Provisions should be made by the A/E for storing water for the EOC if water requirements are to be met with stored water.

(5) Miscellaneous. A substantial number of other items will have to be stored. These items may include: janitorial items, toilet tissue, facial soap, blankets, paper towels, trash containers, laundry detergent and sanitary napkins. This list should be amplified by local authorities and furnished to the A/E.

(6) T tal Storage Space Required Once the quantity of mater& to be stored within the EOC has been determined, the A/E can then compute space requirements. All items will generally be stored in or near the area where they are to be used.

q. Kitchen. In the initial predesign conferences, the requirements for a kitchen have to be established. The size of the kitchen and equipment required will be based on the types of meals to be served, the number of daily meals and the number of people to be served. Kitchen appliances should be electrically operated. For a small EOC a typical conventional home-style kitchen with electric stove, oven and refrigerator would be adequate. Equipment for larger EOC's should be based on recommendations by the A/E. A small dining area will be required. Based on its size, the area may also be used for other functions, such as TV room, movies, briefings, or conferences.

r. Medical Service. A minimal quantity of medical supplies will have to be stored in the EOC. A medical area with one or more beds, sink, shower and toilet facilities is essential. The overall size of this area will be based on the projected EOC staff. It may be desirable to store maintenance medication taken daily by members of the staff. A secure area for all medication should be provided. Space should also be provided which could serve as a temporary morgue.

s. Maps and Disolavs. The EOC will require extensive visual displays. Displays should be fairly large (e.g., 6 ft. x 6 ft., 6 ft. x 10 ft.). Several types of display methods should be devised based on local consultation. For example, some EOC's, based on size, may require multiple displays on some type of track system. For others, simple wall mounts may be adequate. All of these items.can.be.resolved in predesign conferences. Displays may have to be retained for several days and overlays may also be required. An overhead projector with viewgraphs and screen may also be appropriate. Displays and maps may require storage space. If displays are to be kept mounted on the panels for immediate recall or use, then the display system will require a fairly large area even if most of the wall areas are used.

t. Fire Protection. The EOC should be of permanent noncombustible construction. The building should meet the requirements of NFPA #l0l Business Occupancy. Adequate means of egress are to be provided. One hour fire walls should be provided around the mechanical room and two hour fire walls around stairs. All ductwork penetrating the mechanical room walls should be provided with fire dampers. A complete automatic fire detection and alarm system should be provided for the facility. The fire alarm systems should be provided with their own battery backup. Visual fire alarm warnings should be provided as well as the usual audible signals. The alarm system should also be capable of being activated manually. Provisions should also be made for expelling smoke from the EOC rapidly. Depending on the location of the EOC structure, a decision will have to be made as to the installation of an automatic fire sprinkler system. An automatic fire sprinkler system should be considered for the EOC and should be installed in accordance with local building codes.

u. Dormitories. Separate sleeping areas for men and women should be considered in the basic EOC design and space allocation. The dormitories should be designed to permit 50 percent of the staff to sleep or rest at the same time. Thirty-inch wide cots may be adequate. The cots or beds selected should have the ability to be collapsed and stacked or perhaps folded against the wall when not in use. Space should also be allocated to furnish each of the people in the EOC a small wall mounted locker, similar to those found in air, bus or rail terminals. Lockers should be approximately 1 cubic foot.

v. Facilities for the Physically Handicapped. The EOC should be accessible to and usable by people with physical disabilities. Accessibility and usability allow a disabled person to get to, enter, and use a building or facility. Design criteria for the purpose of ensuring that the EOC is accessible to the physically handicapped, shall be in accordance with criteria set forth in the American National Standards Institute document, ANSI A117.1 - 1980, Physical Handicapped Accessibility. Special attention should be given to such architectural design components as vehicular traffic routes, interior traffic routes, protruding objects, ground and floor surfaces, curbs and ramps, stairs, elevators, doors, drinking fountains, light switches, toilet facilities, kitchen and dining facilities, handrails, grab bars, alarms, telephones, and accommodations.

C. MOBILE OR TRANSPORTABLE COMMAND CENTERS

1. General. Mobile or Transportable Command Centers **(MTCC's) can enhance** survivability of State and local direction and control operations by functioning with, or in place of, the fixed EOC in crises periods such as nuclear attack, manmade and natural disasters. MTCC's have the added advantage in natural disasters as they can be utilized to provide command posts for localized field operations. The FEMA-sponsored report entitled State and Local Mobile Command Centers for Emergency Management provides information about the overall concept and requirements for MTCC's.

2. MTCC Development. The MTCC is envisioned to be a Mobile Operations Facility (MOF) supported by a Mobile Communications Support Center (MCSC), or alternatively, a series of preselected fixed EOC's, preferably located in low risk areas, and a MCSC to provide essential communications support. When a MTCC consists of both a MOF and a MCSC, both elements should be simultaneously transported to a selected site where the two components would be capable of becoming operational with minimum delay, subject to the availability of adequate radiation fallout protection. When the MTCC is

comprised of an MCSC and several preselected fixed EOC's, it will be necessary to demount the user input/output equipment (telephones, facsimile, teletypewriters, etc.) and install them and the remote control communications devices within the EOC which is expected to provide the essential radiation fallout protection. The process would be repeated as circumstances require movement of the EOC to an alternate site.

3. The Mobile Operations Facility (MOF). The MOF provides the facilities and environment in which emergency operations personnel can perform their functions of information gathering, coordination, information dissemination, and decisionmaking. As an economy measure, some, if not all, of the space required for the MOF could be provided by host area structures, but at the risk of slowing reaction time and restricting MTCC locations. On the other hand, a fully self-contained MOF could prove to be prohibitively expensive for many locales, and may be difficult to support logistically.

a. Essentia Characteristics The following are **essential characteristics** of the MOF that the A/E should consider when planning a MTCC system:

(1) Response. The MOF should be maintained in a complete state of readiness, thus requiring little or no preparation for deployment.

(2) Transportability. The MOF should be self-propelled or transportable to the employment site in a single lift.

(3) Size. The MOF should be sufficiently large to transport essential equipment and required personnel. Operating space can be augmented by host areas. Preferably, the MOF would be small enough to take advantage of the fallout protection afforded by locating within an existing structure, unused tunnels, caves, or other facilities modified to provide radiation protection.

(4) Flexibility. In general, more utility will be derived from the MOF if fewer constraints are placed on its location. Thus, requirements such as excessively large briefing rooms, or dependence on a commercial power source, will limit the MOF's employability and flexibility.

(5) Security Secure voice and record communications between State MTCC's and FEMA Regions should be considered as a possible future capability.

(6) **Privacy** An area to permit discussion of sensitive information by'the official in charge is desirable.

(7) Cost. As necessary, consideration should be given to incremental acquisition through modular construction techniques.

4. The Mobile **Communications Support Center** (MCSC). The MCSC provides multimode communication support services to the MOF or fixed EOC by collocating with it and is dependent on the MTCC for life support functions. The MCSC should locate close to or within an existing structure, to take advantage of fallout protection. The MCSC should be designed for unattended operation, with remote control devices capable of being demounted for installation within a fallout protected structure. The MCSC would extend telephones and other input/output (I/O) devices to the MOF or fixed EOC area and operate a message center. Commercial power would be used as available. A representative MCSC consists of four elements:

a. Communications Vehicle. The communications vehicle transports and houses the majority of the MCSC electronic equipment. When established at a field location, the communications vehicle could also function as a message center, if provided adequate radiation fallout protection.

b. **Support** Vehicle The support vehicle transports tools and equipment necessary for field operations. When setup is complete, the support vehicle is used to provide logistic support to the MCSC.

c. Transportable Power. Two generators, each capable of supporting the MCSC, should be provided as secondary and tertiary backup to primary commercial power. The generators can be **truck** or trailer mounted.

d. Environmental Control Unit **(ECU)**. The ECU provides heating and cooling to the communications vehicle. If not integral, the ECU could be transported by truck or trailer and, with suitable handling devices, could be skid mounted for downloading on site.

5. Essential Characteristics of the MCSC.

a. Connectivity The MCSC will provide connectivity with Federal, State, and'local agencies, and emergency operating organizations necessary to ensure continuation of essential functions.

b. Survivability.

(1) In addition to normal hard-surfaced highway mobility, a capability for movement over unimproved roads is desirable. Mobility must be at least equal to that of the MOF.

(2) Essential EMP protection must be provided the equipment in the communications vehicle, as well as the inter-facility cabling.

(3) Fallout protection must be provided by ECU fallout filters, protective clothing for personnel, and the practice of locating the communications vehicle inside an adequately shielded enclosure, or alternatively, providing other means of protection for remote control devices and operating personnel.

c. Caoacitv. The MCSC capacity must be designed to meet the communications requirements of the supported EOC or MOF.

d. Transportability All major MCSC components, tools, and ancillary equipment should be capable of transport in a single lift by the communications and support vehicles and trailers. Physical security and protection against mechanical shock is essential. Download, setup, teardown, and upload must be within the capabilities of the available crew. Time from arrival on-site to full operation should not exceed 12 hours. Teardown and reload time should not exceed 8 hours.

e. Modes and Security The MCSC should offer, in descending order of priority, voice, record, data, and facsimile communications. Secure capability must match that of the systems with which the MTCC is required to interface.

f. Fl xibilitv The MCSC should be configured to provide all MT& users with full access to all available communications modes and transmissions media.

g. Interoperability. Equipment selection should ensure interoperability with AUTOVON, FTS, AUTODIN, and commercial systems, as essential for effective MTCC operations.

h. Responsiveness. The MCSC should be staffed with personnel sufficiently trained and equipped to maintain uninterrupted communications service6 and respond to changing requirements within existing capabilities.

i. Effective.

(1) Ease-of maintenance, with emphasis on modular replacement;

(2) Built-in test equipment supplemented by ancillary test equipment;

(3) Redundancy; and

(4) 30-day level of spares.

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