Project Number: PSM-MS03 -50

DESIGN OF WATER REUSE SYSTEM

An Interactive Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

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Degree of Bachelor of Science

By

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Abstract

This proposal, prepared for the US Army Soldier Systems Center, Natick, MA, aims to design a water reuse system for the Meal Ready to Eat cooking system. We will design the most efficient combination of storage tank, water transport system, and flooring support system while keeping costs down. With the addition of a water reuse system, the Center will incur lower water costs and help prevent the release of harmful contaminants into the environment and complying with local environmental regulations.

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1.0 Introduction and Background

According to its web site, the Soldier Systems Center, located in Natick, Massachusetts "…is a Department of Defense (DoD) installation responsible for the technology, development and engineering, fielding, and provision of our military's food, clothing, shelters, airdrop systems, and Soldier support items that protect and sustain America's military forces." Since the mid-1950s, Natick Labs has developed a large variety of items which improve the quality of life for America's military personnel. Among the research facilities located at this site are: the U.S. Army Research Institute of Environmental Medicine, the U.S. Navy Clothing and Textile Research Facility, the U.S. Coast Guard Clothing Design and Technical Office, and the DoD Combat Feeding Center.

The purpose behind the creation of the Combat Feeding program is to develop meals which satisfy the requirements of specific combat operations. Research is always being conducted in order to make meals more nutritional, compressible, durable, and palatable. Studies have shown that soldier morale is greatly improved when they have been supplied with nutritional, good-tasting meals.

While today's "Meals Ready to Eat" or MREs would still not be a dinner one would choose over, let's say, a homecooked meal, they are a major improvement over the meals served to U.S. soldiers less than a century ago. Up until the early 20th century, most military food rations consisted of either low quality cracker-like bread known as hard-tack and/or canned meats and vegetables which were often preserved with a lot of salt and still often went bad. By World War II, the quality of American meals had improved significantly with the advent of C Rations which were used until they were replaced by MREs in the early 1980s.

While there were other major benefits to the C Rations and the MREs soldiers eat today, the one relevant innovation was the ability to allow these meals to have a longer shelf life. One way in which this is accomplished is by eliminating any biological contamination from the food itself. This is accomplished by first sealing the perishable in an adequate package (today, the traditional can has been replaced with a lighter and easier-to-open synthetic material pouch and then killing off any organisms within the package by heating it to over 240 degrees Fahrenheit.

In the facility in which our project was focused, test meals are prepared on a regular basis and placed in large cast-iron retorts which sterilize the contents of the meals once they are packaged. These retorts work on a similar principle as a pressure cooker in one's kitchen; water is first added to an airtight container and heated, as the temperature of the water increases, the pressure within the tank is also increased, raising the boiling point of the water and therefore allowing it to cook at a much higher temperature than it would under standard conditions. Once these machines have reached the necessary temperature, the heated water is drained and cold water is added in order to cool the contents of the retorts. Once this is done, the packages are sterile and ready to be stored or studied.

Our project involved working with a Physical Packaging Scientist at the DoD Combat Feeding Center in Natick in order to develop a water reuse system for the retort cooling process. Given the amount of cooling water that is used, (upwards of several hundred gallons) the researchers were wondering if there would be any economic or environmental advantages to develop a system that could store and reuse the cooling water several times. These people asked us to investigate this and we volunteered to take on this project as our IQP.

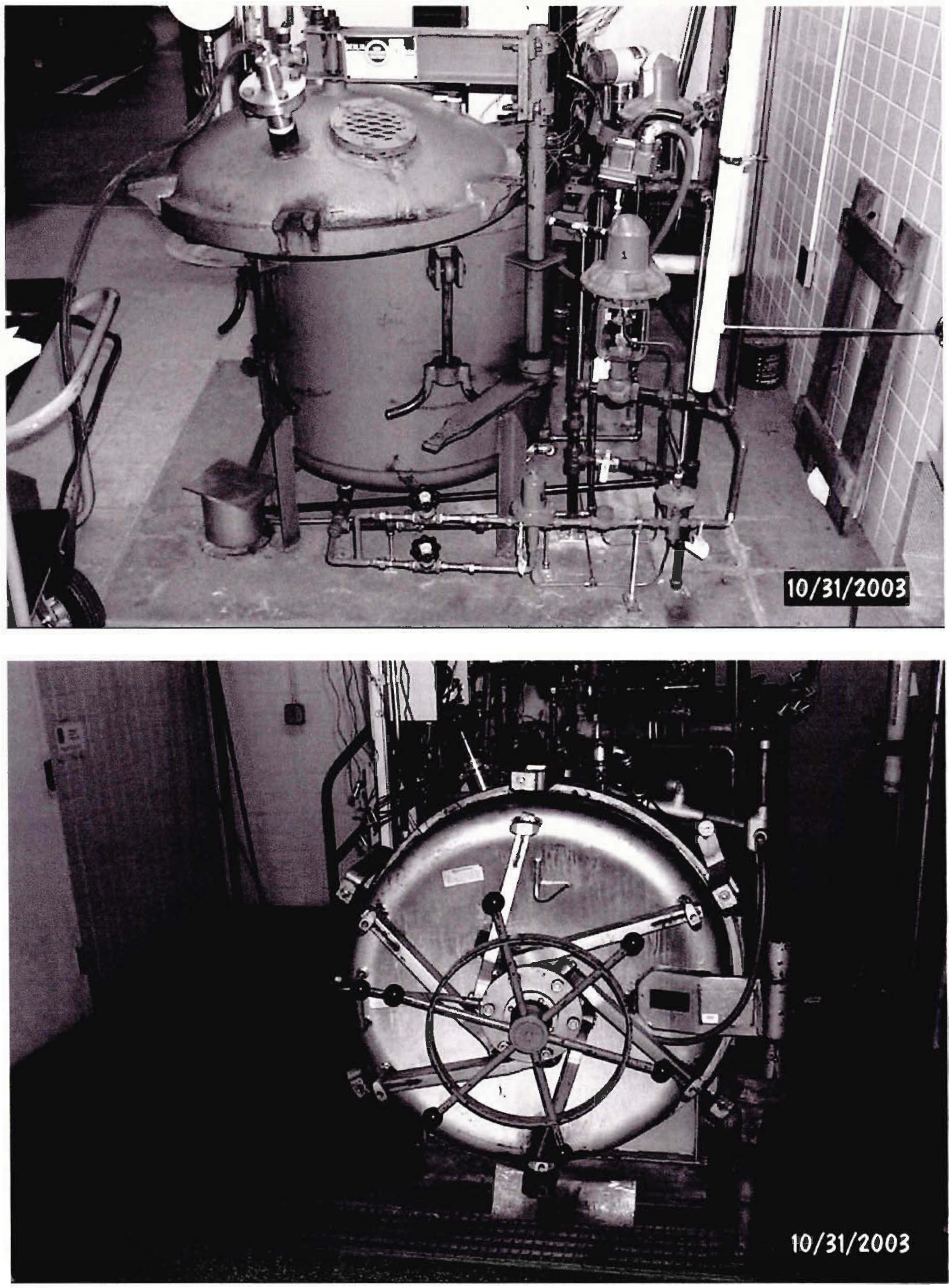


Figure 1: Two of the retorts used to sterilize food packages at the Natick Soldier Center.

2.0 Statement of Objectives

The first objective of this project was to develop a system capable of reusing water that is used to sterilize meals ready to eat packages. A large quantity of cooling water is used to cool the packages after they are heated for sterilization. It is the desire of Natick US Army Soldier Center, Combat Feeding Division to recycle and reuse this water.

The second objective of this project is to design a viable support structure for the water storage system. The water storage system is a large system and has a high weight. A suitable area and means to support it needs to be determined for this structure.

The final objective of the project is to make the design of the system and its support mechanism as cost effective as possible. The design must be near the cost it takes to just dispose of water. It is desirable if the storage system will save the Natick Soldier Center money after a period of time. While cost is a major concern, cost cannot outweigh the efficiency and effectiveness of the system in its design.

3.0 Methodology

As the size and area, along with cost and efficiency of operation, of the system are two of the most important aspects of this system, the first thing we looked at was where to place the main components of the system. There were a number of different options available.

The first option for an area for the water storage system was in the room containing the 75 gallon retort, which is also adjacent to the room containing the larger retorts. This room is on the same floor as the retorts. After performing some measurements, the usable area in this room is 16 feet by 8 feet with a height of 10 feet. This area was currently occupied by a prototype retort and was used as a storage area for some small equipment. This area was soon to be cleaned out and gutted and, therefore, was still a viable option.

The second possible option for an area to place the storage equipment would be to construct some type of storage facility outside adjacent to the Combat Feeding Building. One way to do this would be to construct the water storage tank outside and simply connect it to the retort using an array of pipes. A better option using this method would be to construct some type of shed or housing around the storage tank and other supporting equipment to protect it from the harsh environment possible in New England.

The third option considered for the placement of the storage tank was to remove a section of floor in the room containing the 75 gallon retort. This area would have to be hollowed out and enclosed with water tight walls. The smaller equipment of the system would be placed above the storage tank on the same floor as the retorts.

A final option for area in which to place the components of the system was on the floor above the main floor containing the retorts. The second floor of the building remained unfinished in most areas, but the entire area was designed for a planned second floor that was never built. It contained most of the major structural components necessary for construction of a floor such as a skeleton comprised of W16 by 40 or larger structural I beams. The area that was most favorable for construction was the area directly above the room containing the 75 gallon retort. We were informed that any possible water storage on the second floor was viable and any future construction in that area would be designed around any water storage facility designed in this project.

The best option we saw for placing the water storage equipment was to put it in the open area on the second floor. This option would leave the water storage tank and equipment with enough space around it to perform maintenance. It would also keep it indoors which would reduce the length of pipe required and would protect it from the environment and eliminate any potential heating costs during the winter. It will also keep equipment out of the way of the employees working at Natick Labs and reduce the amount of pipe running through the area.

The next step in this project was to choose a tank size based on the amount of water that would be necessary to store.

The retorts operate by heating a volume of water and then draining that water after sterilization is complete. Cold water is then run through the retort to cool the packages and is discarded as it runs through the machine. This water is the water that is desired to be saved.

Since the retort most often used is a 75 gallon capacity, followed by a 250 gallon capacity, it was decided to be most cost efficient to design for a water storage tank that will store the cooling water for these two retorts. A tank sufficient to meet the needs of these two retorts was determined to be 750 gallons.

The next part of the project that we looked at was the water quality over time. The water, being reused over time, would become more concentrated with different materials over time. The water in Natick is known to contain high amounts of manganese and the retorts are cast iron which will also cause metals to be present in the water. Also, the water may be sitting in the tank for up to two weeks between uses, causing possible bacterial growth or other microorganisms. These two concerns may cause damage to the equipment or improper operation of the retort in sterilization of the food packages.

We decided that to curtail these problems, two small pieces of equipment could be used. The addition of a filter and a small automatic chlorinator would resolve most of the problems that could be associated with metals and bacteria as well as extend the life of the vital equipment of the system.

On a Wednesday in February, we were taken to a water storage and treatment system very similar to the one that we were supposed to be designing. This system is a mercury treatment system. Some of the water leaving the labs in the facility was found to be containing high amounts of mercury waste. This system was set up to store the wastewater and treat it before it was finally sent to disposal.

This system was nearly the identical size and scope of the system that we were designing. The system consisted of a storage tank that was below ground. It contained a variety of filters that were designed to systematically remove the mercury present in the water. The mercury treatment system was very helpful in ensuring us that our design was on the correct path and helped us add a pump of a correct size since the two systems required the water to be moved the same distance.

The last major concern of the system was how best to switch the retort from disposal mode to recycling mode while it is draining. There were a number of different possibilities for this mechanism. The first option is to install a manually operated valve that would reduce costs and complexity, but would be more labor intensive. One other option was to install a timing device to operate a valve but this could be subject to error. The last option is to install an electronic heat sensing device that will automatically open and close the valve at the correct temperatures, but this piece of equipment may be too expensive.

The last piece of equipment needed to complete the water storage and recycling system was an appropriate piping system. We decided that PVC pipe would be appropriate for this type of system as it is also used in the mercury treatment system. A layout of the piping system was also planned out in the simplest way possible while still being efficient and effective.

After all the components were sized and designed for, we then began to look at what specific components from specific companies would be most cost effective for this project while still allowing it to reach its objectives. These components and their operations are shown graphically in Appendix A.

3.1 Suspended Solids Test

One of the first concerns we had before designing this system was the quality of the water that was used for this process. According to our project advisor at the labs, all of the water used by their facility came from the Town of Natick, which he said received most of its water from public wells and has had problems with high manganese concentrations. An additional concern was that the retorts were made of cast iron and were at least 30 to 40 years old and showed a lot of corrosion inside of them.

Manganese is a mineral that is commonly found naturally in some waters, especially well water. While in moderate doses manganese is considered to be non-hazardous to human health, its presence is harmful in a different way. When it enters pipes, appliances, large retorts, etc, manganese can oxidize and turn into manganese dioxide, a black substance which can form on the surfaces it is exposed to. In addition, a disturbance to the water system (such as a broken water main) could potentially release large amounts of manganese buildup which could have been accumulating for years and clog anything in its path.

In order to see if the amount of manganese within the water would pose a serious threat, we obtained recent Natick water quality test results, which can be seen on the following pages.

Since there was no real way for us to predict how much manganese could be released from a disturbance in the water distribution system, based upon the test data, we could see that the levels of this mineral fell within the appropriate federal levels for a drinking water supply, although it was slightly over the limit for secondary, non-enforceable limits. Since we had this data, we also looked at any other potential water quality hazards such as the presence of other minerals, chlorides and sulfides, and pH, which we were pleased to see all fall under acceptable levels.

Another problem previously mentioned was that the inside of these large retorts were completely lined with a layer of rust. Our group was concerned about how much rust was being dissolved by the water during each cycle which, along with the manganese and whatever else was in the water, could potentially clog up our system. In order to confirm that the amount of rust in the water would not pose a hazard, we decided to conduct a simple laboratory test to determine the amount of suspended solids within a sample of retort cooling water effluent.

Figure 2: Interior of one of the retorts, lined with rust.

Back at the environmental engineering water quality lab at WPI, our research group conducted a simple test to determine overall the amount of suspended solids which were floating around within our water samples.

3.1.1 Method

*Note – We originally conducted this experiment with 250mL of retort effluent but this was not enough volume to obtain conclusive results and a second sample of 17 Liters was used for a second test.

We first obtained a Whatman Type 934/AH glass fiber filter and cleaned it by attaching it to a suction device and passing water through it. Once this was done, we placed the filter in an evaporating dish and heated it in an oven at 103 to 105 degrees Celsius for one hour. After this was done, we placed the filter and dish to cool for 30 minutes in a desiccator in order to keep it dry while cooling.

Once the cleaning process was complete, we then weighed and recorded our clean and dried dish and filter; taking precautions not to handle the dish with our bare hands as the oils from our skin could add extra mass to the system and throw off our results. We then reattached the filter to the suction device and slowly passed our water sample through it, taking care not to clog it. Once the sample was completely passed through, we recorded the actual volume passed through and dried the filter using the same method we used during the cleaning process. After the filter was thoroughly dried and cooled, we reweighed the filter and dish. The difference between these two weights was the weight of the suspended solids from our sample.

3.1.2 Results

After calculating our data, we determined that the concentration of suspended solids (greater than or equal to 1.5 micrometers) ended up being roughly 1mg/liter, which is a very low amount. Based upon these results, any sedimentation which might occur in our system would probably be the result of much larger periodic flaking and not fine sediments, therefore we decided a 20 micron filter and possibly a wire mesh screen should be sufficient in keeping any sediment out of the system. The results can be seen in Appendix B.

4.0 Design and Cost

The general layout of the water storage system is laid out in the following order. The water will begin in the storage tank where it is held until it is needed to be used. The water will then travel down through the retort to cool the packages. It will then be pumped back up to the storage tank. Before it reaches the storage tank, the water will pass through the filter and an automatic chlorinator. It will then end up in the tank where it is ready for use again.

4.1 Design of Water Storage Tank and Related Parts

4.1.1 Water Storage Tank

The biggest and most important component of this system is the water storage tank. It was determined to be necessary to be a size of 750 gallons. The tank we decided to use was a 750 gallon vertical polyethylene storage tank from American Tank Company. The polyethylene structure is highly impact and chemical resistant. The tanks are molded from one piece of linear polyethylene without joints or seams that may leak. The tanks are constructed from FDA approved materials and will not rust or cause any type of residue. It can also withstand temperatures up to 140 degrees Fahrenheit. It also includes a 16 inch threaded manway containing a 5 inch vented inspection port for easy access to the tank for inspection or full drainage capability with a siphon. Additional fittings can also be added to the tank easily. It is guaranteed for three years. Its total cost is $530.19.

Figure 3: Various tank sizes offered by the American Tank Company

One recommendation on the operation of the storage tank is to clean it out in regular intervals. The water should be replaced every six months to ensure it does not become stagnant or overly concentrated with any material. Once every year, when the water is being drained he tank should also be flushed to remove any possible solids that have settled and to remove any possible growth on the walls of the tank.

4.1.2 Filter System

The next piece of equipment necessary for the water storage system is the filter and its housing. A 20 inch Big Blue Housing was chosen for this project. The large capacity of this housing is designed for high flow rates that may be experienced in this system. It will extend the life of the storage tank and other equipment in the system.

It is constructed with a 1 inch inlet and outlet for high flow and heavy sediment removal with minimum pressure drop. The filter is a 20 micron filter designed specifically for this housing. It is designed for medium sediment flow and will remove dirt and rust particles which are the most prevalent solids present in the water. Its pleated walls have a high solids holding capacity. The housing has a cost of $69.99 and the filter is $19.99.

Figure 4: 20" Big Blue Housing and Filter

It is recommended that the filter be replaced every 4 months to ensure it is not clogged. This will ensure efficient filtration of rust flakes from the retorts.

4.1.3 Automatic Chlorinator

Another major component of the system is an automatic chlorinator. This will prevent microorganism growth in the storage tank. The chlorinator chosen is a Hayward In Line

Chlorine Feeder. It holds up to 9 lbs. of chlorine tablets and can treat up to 40,000 gallons of water. It has a manually controlled distribution to control the amount of chlorine released. It can be easily installed into a PVC piping system after the filter. It has a cost of $62.99.

Figure 5: Hayward In-Line Chlorine Feeder

One operational consideration for the chlorinator is the purchase of chlorine tablets. A 50 lbs. bucket of 3 inch tablets costs $79.50. This supply should last a few months due to the probable low amount of disinfection required.

4.1.4 Pump

The final large component of the system will be a pump to move the water from the retort through the filter and chlorinator and back up one floor to the storage tank. The pump will only be needed for that half of the process as the water will be gravity driven as it leaves the tank for the retort. A 1 HP Goulds Booster Jet Pump costs $518.00.

Figure 6: A 1HP Goulds Booster Jet Pump

4.1.5 Pipes, Connectors, and Valves

The last minor components of the system are pipes, connectors and valves. The PVC pipe requirement is approximately 100 feet with a number of elbows and connectors. This cost should be near $120.00. Two 1 inch PVC Union ball valves will also be required to turn off and open flows in the desired directions. These valves will have a total cost of $34.90.

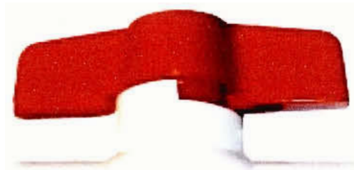


Figure 7: PVC Union Ball Valve

4.1.6 Total Initial Cost

The total initial cost for the water storage system, therefore, should be $1722.67 including a 20% overhead for any problems that may arise. A maintenance cost of $165.47 for filters and chlorine tablets every year would also be added. Most of the major equipment should last for years before minor or major maintenance is required.

4.2 Design of Flooring and Support System

4.2.1 Flooring Area

One floor above the retorts is the frame for the second floor, which is unfinished. The entire floor is framed with no floor, except for a small maintenance and storage area directly above the large retort. The tank will rest on a new platform situated alongside the existing concrete platform. The area to be used as the support system for the 750 gallon tank is 53 $^{1}/_{3}$ ft^2 in size. It is 6′ - 8″ long in the longitudinal direction, and 8′ - 0″ long in the lateral direction. The eastern and western beams, which run the 8′ - 0″ length, are made of W16x40 steel of the I-shaped wide flange variety. The northern member is made of W16x67 steel and the southern member of W16x36 steel, both of the I-shaped wide flange variety. The north-western corner of the rectangular area is supported by an I-shaped wide flange column, and the northern and western beams are mounted directly to it. The northern member has a total length of 19′ - 8 ¾″, and it is connected on the western end to the column. The eastern member is supported by the northern. The geometric center of the 48″ diameter tank will be centered at 3′ - 4″ east/west, and 4′ - 0″ north/south. The tank will have easy service access as there is already an existing ladder leading up to this area directly from the room containing the larger retort. This area is highlighted in Appendix C.

4.2.2 Additional Steel Support Beam

Because of the large weight of the tank when completely full, it is necessary to include an additional support beam in order to counteract the forces acting on the center of the floor and its resulting tendency to sag, causing fractures in and eventually failure of the concrete. Even rebar concrete would not be able to withstand the forces created by a 6000+ lb tank. Therefore, we need to support the concrete floor directly underneath the tank, which will be located in the center of the floor. This beam will be a W12x16 I-shaped wide flange beam. It will span the distance between and be directly connected to the 19′ - 8 ¾″ W16x67 and the 6′ - 8″ W16x36 beams parallel and centered between the two W16x40 beams. The size of W12x16 was chosen primarily based on the height of the member. It's height of 10.8″, when subtracted from the W16x36 member's height of 15.9″ leaves 5.1″, the desired depth of the concrete layer. A diagram of the area with the new steel beam in place can be seen in Appendix C.

4.2.3 Sub-Concrete Steel Decking

Before one can pour concrete on anything but soil, there must be a sub flooring which can support the weight of concrete. The most commonly used method is sub-concrete steel decking. There are many different styles of sub-concrete steel decking available on the market today. The main variables when looking at the many types of steel decking are the style and shape of the corrugation, the gauge of the steel, and the appropriate depth of the concrete when poured over the decking. After much searching, the *Ribdeck E60*, produced by Richard Lees Steel Decking based out of the UK, was chosen based on its efficiency and economical design. This decking, when combined with lightweight structural concrete will provide the tank with a sturdy, long-lasting, inexpensive support system with room for expandability. Unfortunately, since Richard Lees Steel Decking is a UK based company, all of their measurements and specifications were quoted in SI units. Therefore, much conversion was necessary. The *Ribdeck E60* was chosen, with the help of the additional steel beam, because of its large span capability, 8 ½′ (2.44 m), shallow concrete slab depth, 5.1″ (130 mm), and small concrete volume per square footage, 0.308 ft^3/ft^2 (0.094 m^3/m^2). Since the area of the floor to be built is 53 $^1/_3$ ft^2, the total volume of concrete needed is only 16.47 ft^3, or 0.609 yd^3. A print-out of the *Ribdeck* E60 specifications from the Richard Lees website can be seen in Appendix C.

Figure 8: Richard Lees Steel Decking - *Ribdeck E60*

4.2.4 Concrete Flooring

As stated in the previous section, the choice of sub-concrete steel decking leaves us with a particularly small volume to fill with concrete. 3000 psi lightweight concrete was chosen. The weight of the concrete is already considered in the design of the sub-concrete steel decking; therefore there is no need to include these calculations in the determination of whether additional bracing is needed past what has already been discussed. In addition, rebar concrete was not used due to the fact that the tank is to be located directly above the new steel support beam. This beam will be bearing most of the load of the filled tank, and therefore an extremely small deflection in the concrete can be expected. Rebar is typically used in situations where a strong bending resistance is needed in the concrete itself. However, the beam underneath the concrete will do the bearing of the bending moment, leaving the concrete to handle the compression force above the beam. The concrete will be poured to a depth of approximately 5.1 inches and will be professionally leveled and smoothed. Figure 1 shows a cutaway view of the concrete, sub-concrete steel decking, and mid-span support beam and their relationships.

4.2.5 Cost Estimate and Construction Notes

4.2.5(a) Additional Steel Beam

The cost for 50 ksi structural steel, such as what will be used, is at $569.46 per metric ton. The cost for this beam will therefore be minimal. At 8 ft long and weighing 16 lbs/ft, the 128 lb beam will only end up costing $28.48 for the raw material. Labor rates are currently at $36.33 per hour for a structural steel worker. Budgeting $500-$750 for the beam and its subsequent installation does not seem unreasonable.

4.2.5(b) Sub-concrete Steel Decking

The 0.9 gauge Ribdeck *E60* costs $3.50 per square foot for the raw material. Our coverable area is 53 $^{1}/_{3}$ ft^2. The total cost for the decking alone will be $186.66.

Additional costs incurred for delivery and installation will likely bring the final cost estimate into the $300-$500 range.

4.2.5(c) Concrete

The sub-concrete steel decking chosen yields a volume of 0.308 ft^3/ft^2 to fill with concrete. Since the area to be filled with concrete is 53 $^1/_3$ ft^2, this brings the total volume to 16.47 ft^3, or 0.61 yd^3. The 3000 psi concrete to be used is currently priced at $72.25 per yd^3. The total price for the concrete alone comes to $44.08. With the additional costs of transportation, pouring, and leveling & finishing, a reasonable final cost estimate for the concrete is approximately $500-$1500.

4.2.5(d) Final Cost Estimate

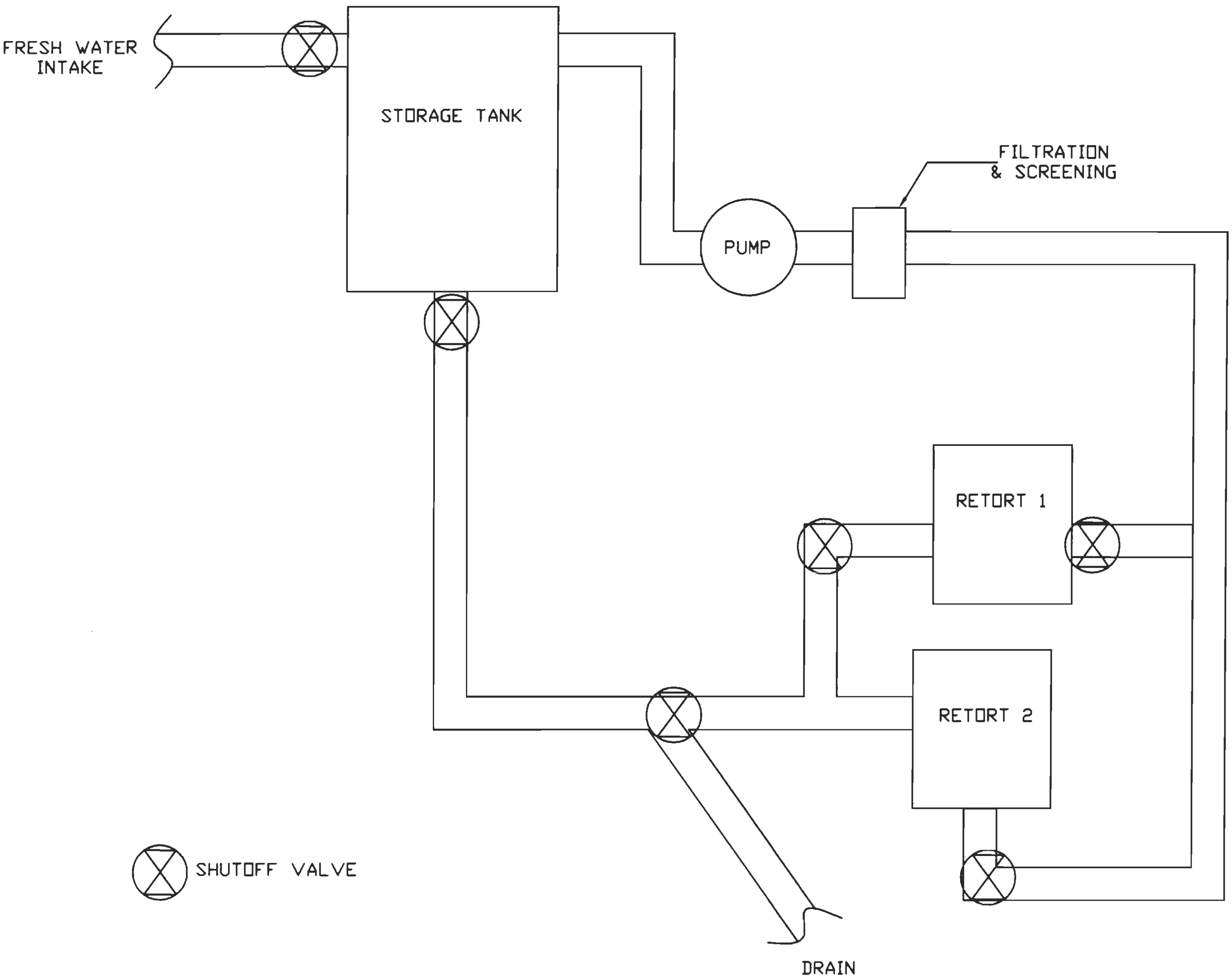
Assuming the worst case scenario, the entire flooring system would benefit a generous budget of approximately $3000 total cost to completion. This is taking into consideration the aforementioned quotes of $750 for the steel beam, $500 for the sub-concrete steel decking, and $1500 for the concrete. This brings the price to $2750. The addition of a $250 buffer is recommended in the case of the project going over budget. The single part of the system with the most possible variance is that of the concrete. This is because it is a balance between quality and price when choosing who to hire to do the finishing job. In this particular case, a smooth, professional finish is not absolutely necessary because of its low visibility. However, smooth finishes assist in cleaning and general maintenance as well.

5.0 Conclusion

When we weigh the positives and negatives of having a system such as this, the main problem we encounter is the price. Assuming the Lab uses 750 gallons per week for 52 weeks a year, and assuming that water costs $1.50 per cubic foot, since there are 7.5 cubic feet in one gallon, the total cost for water in one year works out to $78.00. When we see that the total cost for this system will be approximately $5000.00, we see that it would take almost 65 years to see a return on the original investment. Environmental concerns aside, it seems as though the system, although interesting and good in principal, is simply not worth the cost.

Appendix A

WATER REUSE SYSTEM SCHEMATICS
"NOT TO SCALE"



Appendix B

Primary Drinking Water Standards - **Legally Enforceable**
Public Health Standards
Organic Compounds
As Defined by 310 CMR 22

		Ariem 3rd Floor	Monadnock Spring	Devel. Basement
Organic Compounds	Standard	Site 1	Site 2	Site 3
Benzene	0.005	ND	ND	ND
Carbon Tetrachloride	0.005	ND	ND	ND
Chlorobenzene	0.1	ND	ND	ND
1,2-Dichlorobenzene (o-DCB)	0.6	ND	ND	ND
1,4-Dichlorobenzene (p-DCB)	0.005	ND	ND	ND
1,2-Dichloroethane	0.005	ND	ND	ND
1,1-Dichloroethylene	0.007	ND	ND	ND
1,2-Dichloroethylene(cis)	0.07	ND	ND	ND
1,2-Dichloroethylene(trans)	0.1	ND	ND	ND
Dichloromethane	0.005	ND	ND	ND
1,2-Dichloropropane	0.005	ND	ND	ND
Ethylbenzene	0.7	ND	ND	ND
Hexachlorobenzene	0.001	ND	ND	ND
Styrene	0.1	ND	ND	ND
Tetrachloroethylene	0.005	ND	ND	ND
Toluene	1	ND	ND	ND
Total Trihalomethanes	0.1	ND	ND	ND
Chloroform		0.0028	ND	0.0031
Bromodichloromethane		0.0033	ND	0.0036
Bromoform		ND	ND	ND
Chlorodibromomethane		ND	ND	ND
1,2,4-Trichlorobenzene	0.07	ND	ND	ND
1,1,1-Trichloroethane	0.2	ND	ND	ND
1,1,2-Trichloroethane	0.005	ND	ND	ND

Trichloroethylene	0.005	ND	ND	ND
Vinyl Chloride	0.002	ND	ND	ND
Xylenes (total)	10	ND	ND	ND
Methylene Chloride		0.002	0.00098	0.0008

Units are in mg/L unless otherwise specified
Standards are accurate as of May 2000

Note: Levels of Methylene Chloride are probably due to laboratory contamination. See Lab report for details.

Drinking Water Standards
Inorganic Materials and Metals
Secondary Standards - **Nonenforceable Cosmetic and Aesthetic Guidelines**
As Defined by 310 CMR 22

Metals	Standard		Ariem 3rd Floor Site 1	Monadnock Spring Site 2	Devel. Basement Site 3
Aluminum		0.2	ND	ND	ND
Iron		0.3	ND	ND	ND
Manganese		0.05	ND	0.07	0.13
Nickel		0.1	ND	ND	ND
Silver		0.1	ND	ND	ND
Sodium		20	51	13	50
Zinc		5	0.13	ND	ND
Turbidity	Special		ND	ND	ND
Odor (number)		3	1	1	1
Color (Units)		15	ND	ND	ND
pH	Range 6.5-8.5		7.2	6.6	7.1
Dissolved Solids, Total		500	260	60	280
Chloride		250	99	22	90
Sulfate		250	15	6.8	14
Corrosivity	NonCorrosive				

Methyl Teriary Butyl Ether	0.02-0.04	ND	ND	ND

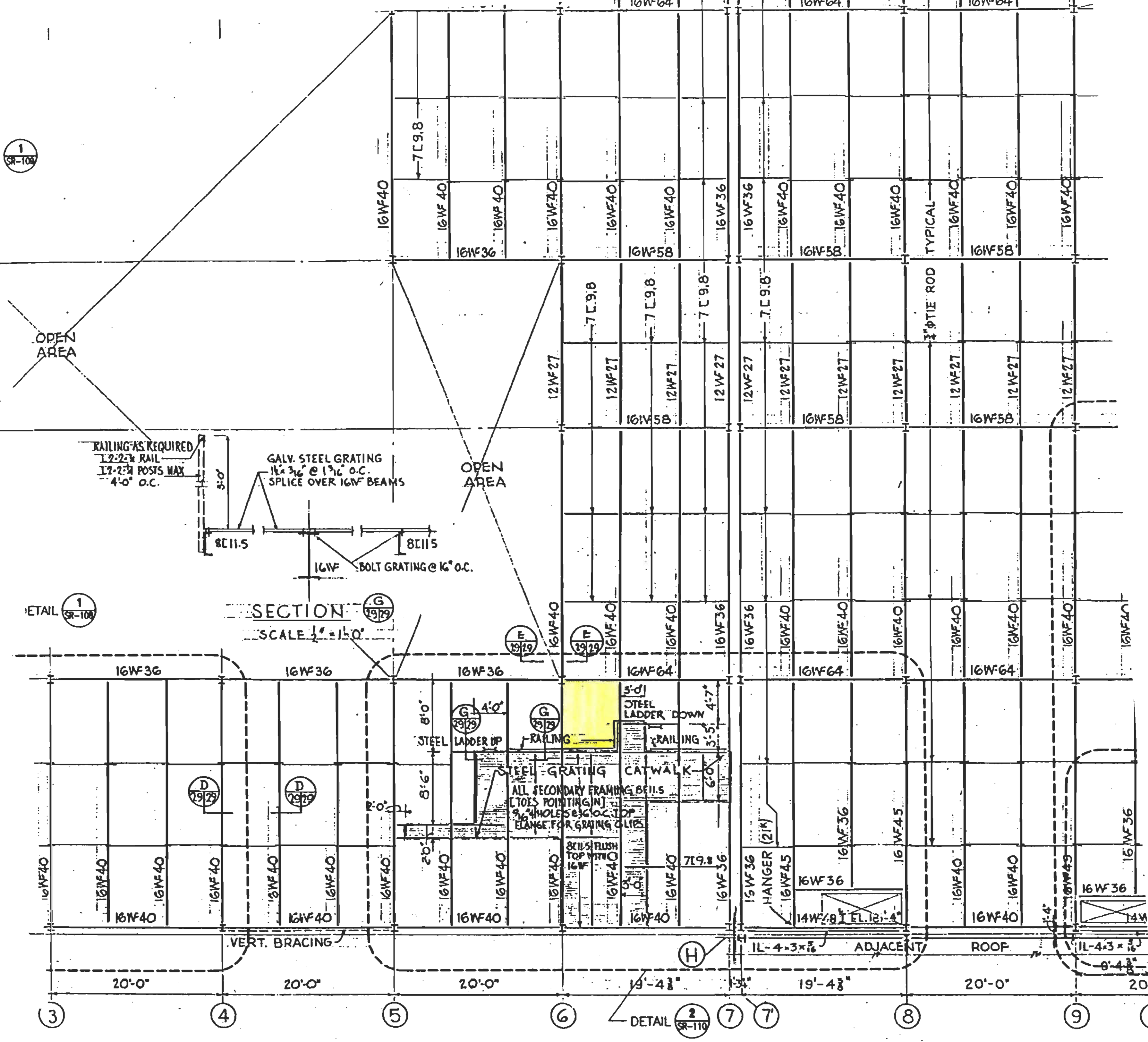
All units are in mg/L unless otherwise noted
Standards are accurate as of May 2000

Items that are not-regulated but were tested

Metals	Standard	Ariem 3rd Floor Site 1	Monadnock Spring Site 2	Devel. Basement Site 3
Calcium #		39	7.8	38
Magnesium #		7	1.5	6.9
Potassium #		3.3	ND	3.3
Alkalinity #		57	15	56

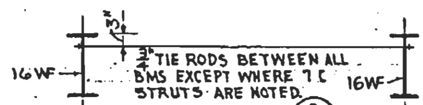
39

Appendix C



CEILING FRAMING PLAN

SCALE ⅛"=1'-0"



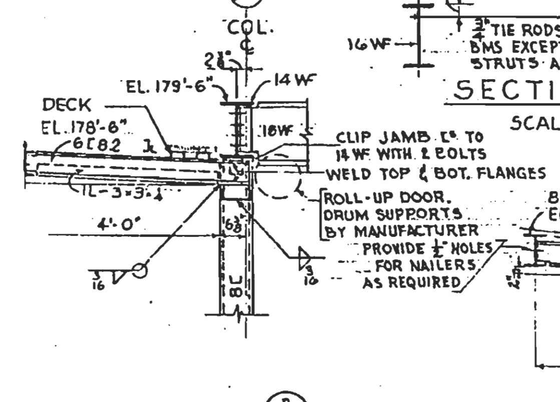
SECTION D 29/29 TYP.

SCALE: ½"=1'-0"

NOTES:

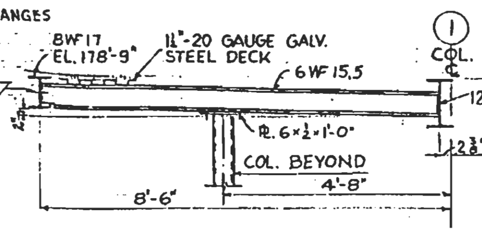
UNLESS OTHERWISE NOTED

1. TOP OF STRUCTURAL STEEL BEAMS ELEV. 179'-6"
2. FRAMING IS DESIGNED FOR FUTURE 100 P.S.F. LIVE LOA[D] 50 P.S.F. DEAD LOAD.
3. FOR STRUCTURAL STEEL NOTES AND GENERAL NOTES.
4. FOR COLUMN SCHEDULE SEE SHEET 33.
5. PROVIDE 1⅜" Φ HOLES FOR FUTURE BEAM CONN[ECTIONS] SAG AND TIE RODS.



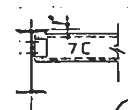
SECTION B 29/29

SCALE: ½"=1'-0"



SECTION C 29/29

SCALE: ½"=1'-0"



SECTION E 29/29 TYP.

SCALE: ½"=1'-0"

SECTIO[N]

SCALE

Another Revolution In Steel Decking

Now there's yet another breakthrough from Richard Lees Steel Decking: one that will save you time and money.
It's called Ribdeck *E60* and it has all the classic abilities of traditional composite steel decking with this ground breaking difference - **Ribdeck *E60* uses less concrete than other decks.**

Less Concrete. More Savings

For given slab depths, Ribdeck *E60* requires lower volumes of structural concrete topping than other comparable decks from the UK and possibly elsewhere in the world. Its advanced design brings a new dimension to the efficient construction of shallow slabs, allowing optimum composite characteristics to be combined with minimum concrete volume.

And More Strength

Ribdeck *E60* has other benefits too:
Extra strength and enhanced spanning characteristics:
Ribdeck *E60* is manufactured from S350 grade galvanised high yield steel strip.

Comparison table showing concrete usage

Slab Depth	Concrete Volumes m^3 per m^2: Typical Trapezoidal Profile	Typical Re-entrant Profile	Ribdeck *E60* Profile	Concrete savings with Ribdeck *E60*: Typical Trapezoidal	Typical Re-entrant
120	0.095	0.111	0.084	13.1%	32.1%
150	0.125	0.141	0.114	9.6%	23.7%

Ribdeck *E60* Span/Load table - Normal weight concrete

Support Condition	Slab Depth (mm)	Concrete Volume (m^3/m^2)	Maximum Permissible Spans (m): 0.9mm GAUGE IMPOSED LOAD (kN/m^2) *	5.0	6.7	10.0	1.0mm GAUGE IMPOSED LOAD (kN/m^2) *	5.0	6.7	10.0	1.2mm GAUGE IMPOSED LOAD (kN/m^2) *	5.0	6.7	10.0
SINGLE	120	0.084	2.98	2.98	2.98	2.44	3.36	3.36	3.26	2.60	3.60	3.60	3.60	2.87
	130	0.094	2.89	2.89	2.89	2.58	3.27	3.27	3.27	2.76	3.62	3.62	3.62	3.06
	140	0.104	2.82	2.82	2.82	2.72	3.18	3.18	3.18	2.92	3.53	3.53	3.53	3.25
	150	0.114	2.75	2.75	2.75	2.75	3.10	3.10	3.10	3.07	3.45	3.45	3.45	3.45
	175	0.139	2.60	2.60	2.60	2.60	2.94	2.94	2.94	2.94	3.27	3.27	3.27	3.27
	200	0.164	2.48	2.48	2.48	2.48	2.80	2.80	2.80	2.80	3.12	3.12	3.12	3.12
MULTIPLE	120	0.084	3.40	3.40	3.03	2.44	3.77	3.77	3.26	2.60	4.07	4.07	3.67	2.87
	130	0.094	3.31	3.31	3.22	2.58	3.67	3.67	3.47	2.76	3.98	3.98	3.94	3.06
	140	0.104	3.22	3.22	3.22	2.72	3.58	3.58	3.58	2.92	3.90	3.90	3.90	3.25
	150	0.114	3.14	3.14	3.14	2.87	3.49	3.49	3.49	3.07	3.80	3.80	3.80	3.45
	175	0.139	2.96	2.96	2.96	2.96	3.30	3.30	3.30	3.30	3.61	3.61	3.61	3.61
	200	0.164	2.79	2.79	2.79	2.79	3.14	3.14	3.14	3.14	3.45	3.45	3.45	3.45
PROPPED	120	0.084	4.20	3.19	2.79	2.31	4.20	3.43	2.98	2.45	4.20	3.88	3.33	2.69
	130	0.094	4.55	3.35	2.93	2.43	4.55	3.62	3.15	2.58	4.55	4.11	3.53	2.85
	140	0.104	4.90	3.50	3.07	2.54	4.90	3.78	3.30	2.71	4.90	4.32	3.72	3.00
	150	0.114	5.25	3.64	3.20	2.66	5.25	3.95	3.45	2.84	5.25	4.53	3.90	3.16
	175	0.139	5.89	3.97	3.50	2.92	6.12	4.32	3.79	3.13	6.12	5.00	4.33	3.52
	200	0.164	5.60	4.25	3.77	3.16	6.41	4.65	4.09	3.40	6.50	5.41	4.71	3.84

* Denotes decking used as shuttering only.

Notes:

1. Spans shown assume clear span +100mm to the centreline of supports.
2. Designs are fully in accordance with BS 5950: Parts 4 & 6.
3. The dead weight of the slab has been included in the development of the spans shown. However, consideration should be given to finishes, partitions, walls, etc. when reading from the table.
4. Based upon concrete densities at wet stage: normal weight concrete 2400 kg/m^3, lightweight concrete 1900 kg/m^3.

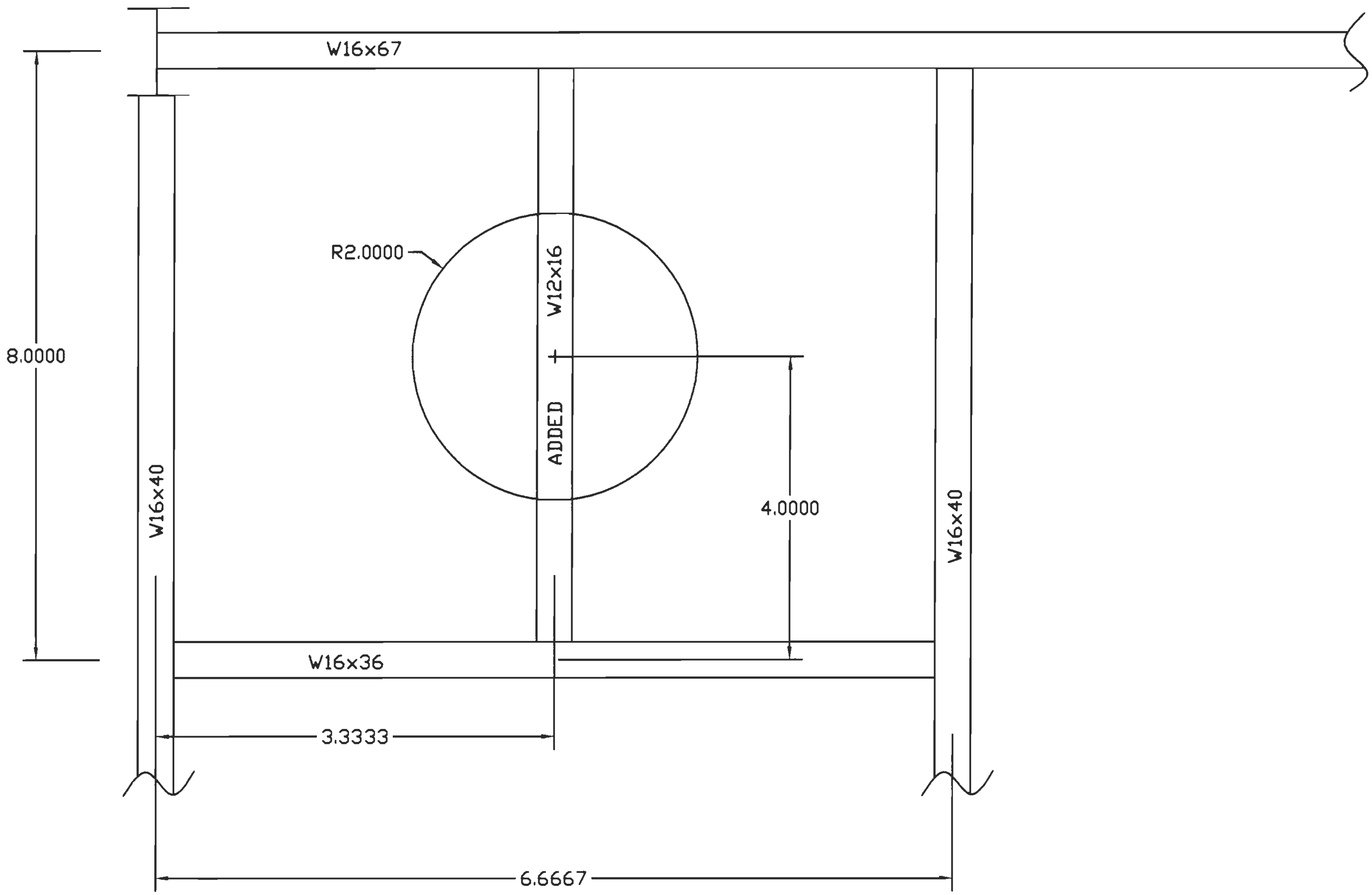
Mesh sizes for Simplified Fire Designs - Normal weight concrete

	Fire Rating (Hrs)	Slab Depth (mm)	Span (m) for given Imposed Load (kN/m^2): A142 5.0	6.7	10.0	A193 5.0	6.7	10.0	A252 5.0	6.7	10.0
NORMAL WEIGHT CONCRETE	1.0	130	3.62	3.28	2.83	3.93	3.56	3.07	4.24	3.84	3.31
		140	3.79	3.44	2.98	4.12	3.73	3.23	4.45	4.04	3.49
		150	3.87	3.52	3.05	4.20	3.82	3.32	4.55	4.14	3.59
		175	--	--	--	4.34	3.97	3.47	4.70	4.30	3.75
		200	--	--	--	4.46	4.10	3.61	4.82	4.43	3.89
	1.5	140	3.32	3.02	2.61	3.65	3.31	2.87	3.98	3.61	3.12
		150	3.46	3.15	2.74	3.82	3.47	3.01	4.17	3.79	3.29
		175	--	--	--	3.96	3.62	3.17	4.33	3.96	3.46
		200	--	--	--	4.06	3.73	3.28	4.43	4.08	3.58
	2.0	150	3.08	2.81	2.44	3.44	3.13	2.72	3.80	3.46	3.00
		175	--	--	--	3.64	3.33	2.91	4.03	3.68	3.22
		200	--	--	--	3.72	3.42	3.01	4.11	3.79	3.33

Notes:

1. Tables are applicable for any construction where the mesh may act in tension over a supporting beam or wall (negative bending). This includes end bay conditions i.e. the **concrete slab** is continuous over more than one span.
2. Loads shown are unfactored working loads and should include all imposed live and dead loads, excluding only the self-weight of the slab.
3. An ultimate load factor of 1.0 is assumed throughout.
4. -- indicates that the area of mesh is less than the minimum for crack control recommended in BS5950: Part 4

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE STATED



NOTE: A 5.08" THICK CONCRETE FLOOR SHALL BE POURED TO SUPPORT THE TANK