AFRL-ML-TY-TR-2004-4520

Air Deployable Caustic Mixing System

John L. McKelvey, John F. Shanahan

Case Engineering, Inc.
5925 Imperial Parkway, Suite 226
Mulberry, FL 33860

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AIR FORCE RESEARCH LABORATORY
MATERIALS & MANUFACTURING DIRECTORATE
AIRBASE TECHNOLOGIES DIVISION
139 BARNES DRIVE, STE 2
TYNDALL AFB FL 32403-5323

NOTICES

THIS TECHNICAL REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION.

– S –
JAMES A. HURLEY
Program Manager

– S –
MICHAEL J. CALIDONNA, Maj, USAF,
Chief, Weapons Systems Logistics Branch

– S –
JIMMY L. POLLARD, Colonel, USAF
Chief, Airbase Technologies Division

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*: 29/03/2004

2. REPORT TYPE: Final

3. DATES COVERED *(From - To)*: 17/06/2003-29/03/2004

4. TITLE AND SUBTITLE
Phase I SBIR, "Air Deployable Caustic Mixing System"

5a. CONTRACT NUMBER: F08630-03-C-0210

5b. GRANT NUMBER:

5c. PROGRAM ELEMENT NUMBER:

5d. PROJECT NUMBER:

5e. TASK NUMBER:

5f. WORK UNIT NUMBER: 6001E39H

6. AUTHOR(S)
John L. McKelvey and John F. Shanahan

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Case Engineering, Inc.
5925 Imperial Parkway, Suite 226
Mulberry, Florida 33860

8. PERFORMING ORGANIZATION REPORT NUMBER
Project No. 3160

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFRL/MLQ
Mr. James A. Hurley
139 Barnes Drive, Suite 2
Tyndall AFB, Florida 32403-5323

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/MLQ

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-ML-TY-TR-2004-4520

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

Distribution A: Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Report developed under SBIR Contract for Topic 03-018. The modular skid mounted system designed in the Phase I effort is an air-transportable batch chemical blending and storage system. It is capable of preparing a mixed hydroxide (MOH) solution composed of potassium hydroxide (KOH), sodium hydroxide (NaOH) and lithium hydroxide (LiOH) using dry alkali hydroxide raw material and de-ionized water at a rate of 3678 lb/hr (166 8 kg/hr). The system is capable of producing 11,036 lb (5006 kg) of mixed hydroxide solution in just over 3 hours within an accuracy of 0.5% of its target recipe requirements. Each module will have quick-connect power and communication leads from a central power distribution and process control station. The necessary transformer requirements for the system have been calculated as 750kVA. Such a system when combined with a peroxide mixing system can provide reliable and essential support for the air borne laser.

15. SUBJECT TERMS
SBIR Report, Caustic, Mixed Hydroxide, Potassium, Sodium, Lithium, Air Deployable, Blending, Storage, System, MHP, Airborne Laser

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			James A. Hurley
Unclassified	Unclassified	Unclassified		98	19b. TELEPHONE NUMBER *(Include area code)* 850/283-6243

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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CASE ENGINEERING, INC.
5925 Imperial Parkway, Suite 226 • Mulberry, FL 33860

PHASE I SBIR

FINAL REPORT

for the

AIR DEPLOYABLE CAUSTIC MIXING SYSTEM

CONTRACT NO. F08630-03-C-0210

March 29, 2004

Fax (863) 701-7671 www.caseinc.com Phone (863) 701-2822

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EXECUTIVE SUMMARY

The unit designed in the Phase I effort is an air-transportable batch chemical blending and storage system. It is capable of preparing a mixed hydroxide solution composed of potassium hydroxide (KOH), sodium hydroxide (NaOH) and lithium hydroxide (LiOH) using dry alkali hydroxide raw material and de-ionized water at a rate of 3678 lb/hr (166 8 kg/hr). The system is capable of producing 11,036 lb (5006 kg) of mixed hydroxide solution in just over 3 hours.

A batch mixing system was chosen as the optimum process configuration to suit the objectives listed in the solicitation. The system will be divided into modules that will accommodate transport aboard cargo planes. Each module will have quick-connect power and communication leads from a central power distribution and process control station. The necessary transformer requirements for the system have been calculated as 750kVA.

The air-transportable caustic production system is separated into the following sub-systems: Dry solids handling modules and batch dilution tank modules, the mixed MOH make-up tank module, de-ionized water module, chilling module and the power and control module. Neutralization chemicals, tanks, pumps and instrumentation to properly dispose of system waste solutions are not included in the system.

In addition, a theoretical accuracy study is presented that proves the system is capable of meeting the MOH recipe requirements within 0.5% by weight of its target. Material options for various equipment components are also presented.

It is noteworthy that the caustic mixing system design rates can produce enough mixed base solution to complement a mixed-base hydrogen peroxide solution (MHP) mixing systems operating at rates up to 534 gallons per hour (2,538 kg/hr). The integration of the caustic mixing system with a peroxide mixing system can form a completely air transportable MHP production system that can be tested, developed and constructed to support the air borne laser.

1.0 OBJECTIVES

The primary objective is to design an alkali mixing system capable of producing solutions of potassium hydroxide (KOH), sodium hydroxide (NaOH) and lithium hydroxide (LiOH) at a sufficient rate so as to produce enough mixed alkali hydroxide solution to satisfy the requirement of producing a minimum of 1,000 kg/hr.

Although not specified in the solicitation, it would be desirable to exceed the capacity requirement and design a caustic mixing system that satisfies the raw material requirements for a peroxide addition system. The peroxide combined with the mixed-base (MOH) solution would yield the essential chemical necessary to drive the chemical Iodine laser being developed by Boeing. The design capacity of approximately 5,000 lb/hr (2,268 kg/hr) of a mixed base hydrogen peroxide (MHP) has been proposed in a previous Phase I effort. The design of a caustic mixing system that produces 3,678 lb/hr (1,668 kg/hr) could be combined with the MHP system and form a complete MHP production facility suitable for pilot testing or possibly in-theater production if necessary.

The advantage of having a caustic mixing system using dry hydroxides is to remove the logistic burden and expense of transporting pre-made alkali hydroxide solutions. Instead the system only requires the solid forms of alkali hydroxides reducing expense, weight and volume leading to increased system flexibility. To further the systems adaptability, it is designed to accept different dry alkali hydroxide packaging containers such as drums or super sacks.

Tasks listed for the final report includes:

1. Accumulate information for critical module elements such as pumps, flowmeters, valves, heat exchangers, etc., to enable arrangement, piping and process flow sheet development
2. Develop mass balances using english and metric units
3. Develop an energy balance that defines coolant flows and temperatures to and from heat transfer equipment
4. Develop PID's and design a system that can accommodate dry alkali addition using bulk sacks and drums
5. Develop a Lithium (monohydrate) hydroxide mixing system that is capable of either batch heat exchange using coils in the dilution tanks or allowing heat exchange in the recirculation line around the tank. This flexibility provides for the assessment of the two different types of solution processing and allows for future potential recipe changes such as mixing Lithium (monohydrate) hydroxide with peroxide solutions alleviating water balance constraints.
6. Develop Piping Drawings Accommodating major equipment and critical valves and instruments
7. Develop Electrical single line drawings for the system
8. Develop Arrangement drawings that show the relationship of system as a stand-alone unit or as part of the larger MHP system
9. Theoretically demonstrate that the accuracy requirements of making MOH solutions within 0.5% by weight is feasible with the system design
10. Assess and list alternate materials of construction that can be used for the alkali hydroxide and MOH solutions

2.0 TECHNICAL PROJECT OVERVIEW / CHANGES

2.1 Project Summary / Scope Changes:

The first proposed design concept is shown in figure 1. Initially, the system involved drum-handling equipment. The solid alkali hydroxides (lithium hydroxide monohydrate, potassium hydroxide and sodium hydroxide) would be purchased in drums of various sizes. Operators using appropriate personal protective equipment would open the drums, secure a discharge hopper and mount the drums to the dumping frame. The drum would be automatically elevated and inverted above a tank nozzle. A valve at the end of the discharge hopper prevents the material from leaving the drum until an inflatable seal can be activated that connects the end of the discharge hopper assembly to the tank nozzle. The tank nozzle also has a valve mounted on it. When the seal is engaged, both valves are opened and material flows into the tank. Once empty, the valves would be closed, the drum would be disconnected by deflating the seal, the drum would be lowered back to its starting position. The mechanism would be on load cells and would measure and totalize the differences in weight for each drum loaded onto and off of the frame. A PLC control program tracks and totals the weights until a pre-entered set point is reached.

The remainder of the system was designed to remove the heat formed from the dissolution of the solids in water and allowed for the individual solutions to be mixed in any order of addition. The system capacity was selected to make enough mixed base solution to complement an earlier designed MHP system capable of producing 338 gallons per hour (1580 kg/hr) to 534 gallons per hour (2,538 kg/hr).

Pursuant to a meeting on 10-24-03 with Mr. Jim Hurley, the alkali dilution process was changed. First, the most likely alkali hydroxide storage container was thought to be bulk bags instead of metal lined or plastic drums. Therefore, a system had to be designed to accommodate the emptying of bulk bags or "super sacks".

The second set of constraints presented during the meeting changed the proposed scope of work. In the original proposal, the development of a more continuous mixing module would have been developed that would remove the need for a batch MOH mixing tank and possibly reduce the size of the system in exchange for a more complicated and automated unit. After a brief review of the concept, it was thought that recovery from system errors leading to off-spec MOH solutions would be difficult to correct. Finally, since the upstream introduction of dry materials and subsequent batch peroxide additions in a future MHP system are batch process, the utility of an intermediate continuous flow system module appeared to be a poor use of resources. The development of such a secondary system element was not discouraged, but an alternative was suggested.

Instead of spending resources developing the continuous module shown in Figure 2, advantages were outlined for developing the batch alkali mixing modules to be capable of using different methods of solids introduction and heat exchange. The system shown in Figure 3 represents pneumatic systems that transfer the dry material into the dilution tanks. This system allows all equipment to remain at grade making assembly easier to perform. The disadvantage is that the system has more equipment, becomes more complex from an operations and maintenance standpoint and costs more due to the materials of construction and high quality mechanical components required.

During the review meeting, it was suggested that the development of in-line heat removal equipment would make the system more flexible since internal coils are fixed and difficult, if not impossible, to modify in theater. In addition, should more heat need to be removed because of a change in process chemistry, external heat exchange elements can be added in series to increase transfer area. System hydraulics also could be modified to adjust for the increase in system head. Thus, the system would be more flexible for such changes. In addition to the in-line heat exchange concept, in-line solids dispensing devices were also suggested. This in-line solids eduction equipment literally suctions dry material directly into the circulating liquid or slurry stream. It was not clear if such equipment would have limitations for bulky or large raw material solids, but small crystals would likely be suitable.

The system pictured in Figure 4 eliminates the pneumatic delivery equipment for all three dry materials and presents an alternative dry-solids mixing scheme for lithium hydroxide material. In addition, in-line heat exchange is available on the lithium hydroxide dilution module. This allows for the prototype system to compare various dispensing equipment and heat exchange options with little or no system modifications. In addition, should the system chemistry change by substituting the water to weaker strength peroxide solutions as the solvent, the modified in-line heat exchange option would best suit such a test. Substituting peroxide as the solvent also relieves constraints imposed on the system water balance as well. This subject is explained more completely in the following sections.

Therefore, it was decided that the system pictured in Figure 4 would be pursued and developed instead of the original continuous mixing module.

2.2 Dry Handling Equipment:

It was decided that the likely primary package container would be bulk bags instead of drums. Therefore, the dispensing devices used for dry solids from "super-sack" bulk containers became more important. This required modification of the method used to introduce solids into the batch alkali dilution tanks. There were three general methods considered for accurately dispensing the dry alkali hydroxide material into batch mix tanks. Each had advantages and disadvantages. A brief description of each method is presented in the following sections.

2.2.1 Pneumatic or Vacuum Transfer Systems:

As mentioned, the use of pneumatic or vacuum system transfer was investigated and developed since it allowed the mixing equipment to remain at grade level where all components could be readily accessed for assembly. This method appeared to be safer, but also appeared to involve more complicated equipment to accomplish the transfer compared to a drum dumping system or other gravity-fed system. It should be noted that pneumatic or vacuum systems, such as liquid ring pumps, require a higher degree of maintenance. Troubleshooting units that failed to transfer dry material could prove to be challenging to operators not skilled with chemical unit operations. Nevertheless, the pneumatic or vacuum methods considered were able to accurately deliver dry solids into the dilution tank using intermediate weigh hoppers and did not require elevated platforms. However, the extra equipment to give accessibility advantages lead to increased overall weight.

In pneumatic and vacuum conveying systems considered for this project, a bulk bag is typically suspended from a frame with a monorail and hoist assembly. The spout of the sack is usually passed through a slide gate or pinch valve and banded to a spout. The draw-string on the bag that releases powder from the sack is removed with the slide gate or pinch valve in the closed position. Once the slide gate valve is opened, the solid material flows out of the bag, past a secondary self-cleaning disc-type valve and into the weigh receiver. The material pours into the weigh receiver equipped with load cells until a set point batch weight is reached triggering the closing of the secondary disc-type valve. The weight of the batch is transmitted to the system controller and totaled. The controller then opens the bottom discharge disc-type valve, located immediately beneath the receiver, and allows the material to enter the conveying pipe. The fluid used to convey the solids is dry air being pushed or pulled through the conveying line. Note that a rotary valve located downstream of the introduction point is used to regulate the flow of solids into the dilution tank. The rotary valve speed can be adjusted to minimize local hot spots from forming in the dilution tank.

The driving force necessary to carry the solids into the tank can be created by a vacuum or by compressed air being imposed on the conveying piping system. Vacuum can be created inside the dilution tank before the solids enter or leave the weigh receiver. The vacuum draws the material into the tank above or beneath the liquid water level. One disadvantage is that mist and particulate carry-over from the bubbles breaking at the liquid interface can lead to fouling of in-line de-misters or particulate filters requiring maintenance. In the worst case, more inexpensive "dry" vacuum pumps, which rely on tight metal-to-metal clearances, can be damaged if hard particles break through the filter elements. Liquid ring vacuum pumps can be used that do not rely on tight clearances between hard surfaces and therefore do not share the problem associated with the more inexpensive "dry" vane or lobe type vacuum pumps. Liquid ring vacuum pumps form a liquid seal that traps air and ejects it under centrifugal forces in an eccentric housing. However, these units are expensive, more complex and require skilled operators and maintenance personnel to operate and troubleshoot such equipment.

In the case of positive pressure devices being used such as blowers or compressors, dust filters must be installed to capture fine solids that escape the weigh hoppers or the dilution mix tank itself. Usually, a bag-house filter assembly is needed to capture the solids.

Whether blowers are used or vacuum pumps are used, solids escape from the target tank. Batch errors in weight arise because the solids that have been weighed in hoppers upstream of the mixing tank do not end up in the final mix tank. The only way to account for such losses is to either weigh the mixing tank itself or place both the bag dispensing unit and the solids collection filter assemblies on load cells and account for escaped solids by difference. Weighing the mix tank directly presents operational problems and leads to the load cells being placed on the tank supports where significant forces and vibrations are exerted while the tank is mixing. For tanks using internal cooling coils, the weight of coolant flowing through the coils must be considered as well. Overall, this is a more troublesome and less accurate method of obtaining the total weight of solids entering the tank. Alternatively, weighing the net difference between the solids dispensing frame (or super-sack" frame) and any particulate filtration device assumes there is no solid accumulation in valves hoppers and piping components in the entire conveying system. This could lead to the weight readings calculating falsely high concentrations of caustic solutions than what really exist in the mix tank. Conversely, solids trapped in the conveying path could loosen and be carried into the next subsequent batch transfer leading to an undetected over-charge of solids.

A third disadvantage of these systems is caused by the nature of the material being conveyed. Sodium and potassium hydroxides readily absorb water from the surrounding air and agglomerate or "clump" together causing plugging and fouling in valves and transfer lines over time. To reduce humidity in the transfer system components (the weigh receiver, valves, pipe, etc.), instrument quality dry air can be used as conveying air during a transfer. This will help prevent the deliquescent alkali hydroxide solids from plugging transfer lines. As a result, additional equipment such as desiccant columns or chilled water condensers is required. The introduction of such equipment increases assembly, maintenance and energy consumption requirements.

There are manually operated drum dispensing units available that blow air past a nozzle and literally suck or vacuum the solids from the drum and deposit them into the mix tank. Naturally, there will be some loss of solids for the same reasons as described above. However, if the material is blown under the liquid level in the mix tank, the solids losses can be minimized. By using such a small compact device and by modifying the tank design, drums can be used in an emergency. A nozzle that can accommodate drum transfers has been designed for each alkali hydroxide dilution tank.

The ultimate objective is to accurately introduce solids into the dilution tank in small or large batches until a target weight defined by the recipe has been reached. Each mixing tank system for the hydroxide solutions has a pump and a recirculation loop. In that loop is a mass flow meter capable of measuring the density of the fluid after the solids have dissolved. This in-line instrument can be used in a quality confirmation and control scheme to provide more precise and accurate solutions. If the density is slightly above the target set point, more water can be added to ensure the correct concentration of alkali hydroxide has been made. The converse is also true, but solids additionas are more difficult to perform and would likely involve manual additions of the alkali hydroxide directly into the mixing tanks. This presents safety concerns and defeats the purpose of having an automated and virtually closed system preventing contamination from entering the system. It also would cause longer batch-time intervals to mix the solutions.

2.2.2 Transfer Systems Using Eductors:

The use of vacuum is not necessarily restricted to pneumatic conveying systems. Vacuum can be introduced using eduction mixing devices. These devices use centrifugal type pumping action of process liquid to form a negative pressure on the suction of the device. It is at this point, gravity fed dry solids are introduced into the mixing device. The solids are pulled into the suction and immediately blended with circulating liquid with little or no dry product losses. Such eduction devices can be placed in the mix tank and draw fine solids into the tank or they can be placed in-line, similar to pumps, and located beneath the bulk bag hoppers.

One problem with using devices with dry material is that large crystals or flakes can block and plug the relatively small nozzles associated with these devices. Macerator devices can be added between the hopper discharges and the eductor, but this complicates the design and adds a piece of equipment requiring more skilled operation, trouble-shooting and maintenance. It also provides more places where product can be held-up from entering the liquid resulting in false solution concentration calculations. The second disadvantage is that the humidity created from the circulating fluid can also cause clumping of sodium or potassium flakes. However, using smaller size crystals that do not readily absorb water such as lithium monohydrate hydroxide, the units can be used with a high degree of confidence.

The agitator style eduction units require longer transfer lines and must generate enough suction to overcome the vertical lift of solids into the top of the mix tanks. These devices need conveying lines that offer more area where solids can accumulate resulting in erroneous concentration calculations. Because of the presence of humidity, plugging can occur if routine cleaning between transfers is not performed.

2.2.3 Gravity Transfer Systems:

The most simple and straightforward system is to remove all conveying apparatus and directly feed the solids into the mix tanks. This minimizes the potential for solids build-up between the loss in weight hopper and the alkali hydroxide dilution tank and has the least amount of equipment involved in the transfer. The disadvantage is that to accommodate this arrangement the bulk bag frames and hopper must be elevated and access platforms are required. This complicates assembly, but can be done. It is thought that such systems are excellent for dispensing large, hard-to-handle flake materials since there are fewer components involved in the material transfer. In addition there is no need to use transfer air so all equipment associated with moving the air and collecting fines is eliminated. Finally, if the transfer chutes are greater than the angle of repose for the material, any size solid can be dispensed without concern of fouling and plugging. Ambient humidity remains a concern. However, it is my belief that by using a small amount of dry purge instrument air in key locations, the material can be kept loose and free flowing.

Ultimately, it was decided that two methods would be used to dispense caustic into the system. For the larger and more deliquescent material, such as potassium and sodium hydroxide flakes, the gravity system was chosen. A common platform can be installed that provides access to both the potassium and sodium hydroxide hoppers and valves. The platform, stairway and bulk bag frames can be made into separate modules that can be interlocked and assembled in the field. This is shown in Figure 4.

It was also decided to compare the gravity system with an eduction system that mixes the solids directly with the water. This is desirable since future chemistry might demand that the solids be directly mixed with hydrogen peroxide solutions to reduce water balance constraints. Such recipe changes might also reduce the quantity of equipment necessary to make MHP in the future. The air transportable caustic mixing system will have the ability to compare the two methods of introducing solids into the mixing tanks. The lithium hydroxide monohydrate module was chosen to be modified since it had the smallest particle size and was least deliquescent of all the alkali hydroxide solids. It has the best chance to successfully demonstrate the centrifugal eduction mixer. Furthermore, it is also possible to interchange dry materials and test if KOH or NaOH flakes of various sizes can be used with the mixer. In this way, a very flexible pilot test system has been designed allowing alkali hydroxide solids to be mixed using two different techniques.

2.3 Pumps and Mixing Tanks:

Pumps and tanks for the KOH and NaOH modules have undergone preliminary sizing and selection. To allow the tanks to be interchanged should one become damaged, the volumes are oversized for some of the final alkali solutions. It is anticipated that two batches of NaOH and KOH solutions will be made for every batch of LiOH solution made. Internal tank cooling coils have also been sized accounting for the excess volume. In-line piping components and critical instrumentation (flowmeters) have been sized and selected. Strainers (not shown on Figure 4) and filters have also been selected to protect equipment from large foreign objects.

2.4 Alternate Heat Exchange Configuration:

During the first review, it had been decided there was more benefit developing an alternative to heat removal using internal tank coils. Tank coils are fixed and difficult to change should process requirements demand more transfer area. In-line heat exchangers offer a more responsive alternative. If more surface area is required, either the in-line heat exchanger can be easily modified, replaced with a larger unit or additional exchangers can be added in series with the first exchanger. Obviously, system hydraulics would be affected but increasing the pump impeller and/or motor size or simply replacing the pump could deal with increases in system head.

In addition, a batch mixing system that had in-line solids mixing and in-line heat exchange mimics a more plug-flow type configuration. It is believed that such a system might ultimately lead to the removal of bulky batch system components, thus reducing system size and weight.

The concept is also illustrated in Figure 3 and 4 for the lithium (LiOH) dilution system only. The heat will be removed by an in-line heat exchanger rather than by using submerged coils in the tanks. This offers more flexibility when introducing other chemicals capable of generating more heat than the internal coils can remove. The lithium hydroxide mixing skid design was the only module modified to test the concept of directly metering and mixing solid alkali hydroxide material into the circulating water stream. This feature represents for a pilot test that could reduce the size of the alkali solution tanks and could result in the removal of the internal cooling coils. Regarding future implications when making MHP, the concept of directly adding alkali hydroxide solids into weaker peroxide solutions could result in the elimination of one to two process skids containing tanks and pumps.

2.5 The Dismissal of Developing a Continuous Flow Mixing Module:

During the meeting with Mr. Hurley it was also decided that further development of the continuous mixing module (Figure 2) would NOT be pursued at this time. Therefore, no materials were assembled for this specific subtask. The benefit of making half of the process continuous while still having batch solids introduction and mixing modules offered little advantage compared to the concept identified above.

Therefore, though the continuous mixing module was unique and involved a new mixing alternative, the time was judged to be better spent developing the alternate in-line dry solids feeding and cooling system for the lithium hydroxide module. For more details, see Section 2.1 for details.

2.6 Utilities:

The system has been developed with de-ionized water production capability using potable water typically available at military bases throughout the world. Naturally, the system capability will allow for rapid assembly, operation, production and disassembly. Dry instrument air shall also be provided to actuate valves and purge dry material transfer lines.

It is still assumed that potable water, three phase 460V/ 60 Hz power, neutralization media (for wate stream decontamination and system flushes prior to break-down), a wastewater disposal facility (such as a sewer) and containment shall be available at the proposed sites.

An air-cooled chiller system using a compatible coolant with hydrogen peroxide (Syltherm 800) has been designed to provide the necessary heat removal from the alkali hydroxide dilution steps. The sizing of the unit was made to be nearly identical to a cooling system proposed for a previous MHP mixing system design. The advantage of this fact is that additional MHP equipment can be added to the caustic mixing system without necessarily including a separate chiller system. The only consequence is that the caustic dilution operations could not progress simultaneously with the mixing operation where peroxide and MOH solutions are added together. The system rates could be independently calculated. This saves cost when test system manufacture is considered. Finally, using Syltherm allows limited use of weaker hydrogen peroxide solutions in the caustic mixing system instead of water.

3.0 THE PROCESS DESIGN AND DESCRIPTION:

3.1 The Mass Balance:

Two mass balance flow sheets have been created and are attached to this report. In the calculations used to generate the material balance, impurities that are typically associated with alkali hydroxides have been accounted for. The method used to correct the batch for additional impurities and still maintain the same mass fractions for the alkali hydroxides to adjust the water balance and thereby change the water mass fractions. It should be noted that due to high freezing points for alkali hydroxide solutions, particularly at higher concentrations, there are practical limitations that limit the choices available for alkali hydroxide solution concentrations.

The strategy employed in the balance was to select desired concentrations for NaOH, KOH and LiOH solutions (made in the alkali dilution tanks) and examine the water balance. If the water balance requires more water to be added to the final mixed hydroxide (MOH) solution to attain the correct MHP recipe, then the process is valid and operations can proceed. However, should the water balance be negative, then the initial step is to adjust the NaOH concentration. It can be elevated no higher than 45% due to freezing point limitations. KOH would be the second solution to be adjusted, but it can only be elevated slightly higher than 45% before the freezing point falls into ambient temperature ranges. LiOH solution concentrations should not be adjusted, as it is set near the solubility limit in water. The alkali solution concentrations are adjusted until the water balance is not negative when considering the final MHP formulation.

Information derived from this balance is shown on two flow sheets. 3160-FM-001 represents a flow sheet with metric units used for mass flow rates, densities and temperatures while 3160-FM-002 uses traditional English system units. The material balance represented on the flow sheets minimizes make-up water for the final MOH solution. For simplicity, KOH and LiOH solution concentrations (present in the alkali dilution tanks) shall be fixed at 45% and roughly 10%, respectively. Keep in mind that 10% LiOH is approximately 18% by weight of lithium hydroxide monohydrate solids.

3.2 The Energy Balance:

A preliminary energy balance has been created for the process. It is more simplistic in that it does not consider the contribution of impurities. It was decided that the energy requirement for impurities would be insignificant to the cooling load for each alkali hydroxide dilution tank. The results of the energy balance are reflected by the flows and temperatures listed on the stream entry data panels located on drawings 3160-FM-and 3160-FM-002.

3.3 The PID's & The Process Description:

Attached are seven PID's that define the current direction of the project. They are as follows:\

Dwg. # 3160-F-001	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, Lithium Hydroxide Dilution
Dwg. # 3160-F-002	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, Sodium Hydroxide Dilution
Dwg. # 3160-F-003	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, Potassium Hydroxide Dilution
Dwg. # 3160-F-004	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, MOH Make-Up Tank
Dwg. # 3160-F-005	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, De-ionized Water Module

Dwg. # 3160-F-006	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, Chiller Module
Dwg. # 3160-F-007	Air Deployable Caustic Production System, Piping and Instrumentation Diagram, Plant Air System

Overall, all process lines have been sized and specialty piping items and control valves have been defined. Although figures 3 and 4 show a separate MOH storage tank, the MOH mixing module tank is large enough to serve as a storage vessel. Currently, there is no separate storage tank shown on a PID.

3.3.1 General Overview

The air deployable caustic mixing system design is based on combining chemical processing technology with readily available components to make essential precursor liquid solutions necessary for MHP (mixed base hydrogen peroxide) production. The ultimate purpose is to create a system capable of using dry alkali hydroxide products in any ratio with water to produce any desired concentration of lithium, potassium or sodium hydroxide solutions. The final MOH solution must be made with a reasonable degree of accuracy that is equal to or less than 0.5% cumulative error in the system. It must also be able to mix the individual lithium, potassium or sodium hydroxide solutions in any order to create the final MOH solution. This is important since the order of addition can eliminate or cause the formation of precipitates. In addition, the system must be air-transportable and relatively simple to operate and troubleshoot in the field. Finally, by our firms choice, the caustic production system rate was selected to complement a previous system design proposed for MHP production using vendor supplied alkali hydroxide solutions (See Section 3.1 for details).

To accomplish this, there were two types of systems proposed. Both had common batch solids mixing tanks for the preparation of lithium, potassium and sodium hydroxide solutions. In view of how the dry material will be supplied to the site (in drums or super-sacks), there is no continuous method of introducing the solids into the tank and creating a solution. Therefore, both systems proposed had common batch-wise solids mixing tanks. One system used pumps, flowmeters and a common MOH mix tank to create the MOH solution. This process involved the addition of a second batch mix tank (the MOH tank) and all associated cooling devices. The second proposed system used a more continuous approach to mixing the three alkali hydroxide solutions. It involved the use of pumps, flowmeters, multi-port valves and mixing elements forming a "continuous mixing module". The idea was to eliminate the MOH tank and mix all three solutions simultaneously. The multi-port valves would allow for various orders of addition to prevent precipitation. The advantage of the concept was to reduce the space and weight associated with a larger mix tank skid. The disadvantages are

1. More complex equipment would have to be used
2. More complex system automation and programming would be involved and
3. The difficulty associated with recovering from system upsets that would cause the recipe mass ratios to fall outside the specified accuracy limit.

Based on a review meeting held early in the development of the concept, the batch system was selected for development with further flexibility rather than developing the continuous mixing module. The additional flexibility mentioned was to incorporate different solids mixing and heat removal equipment that would permit the future introduction of chemicals other than water as the solvent. The reason this is a significant advantage is explained by considering the effects caused by water balance constraints.

If the individual batch mixing skids for lithium, potassium and sodium hydroxide could be modified to use weaker hydrogen peroxide solutions, then the water balance constraints can be altered. Due to the insolubility of lithium hydroxide monohydrate in water, the lithium hydroxide solutions have to be the most dilute solution made. Since the MHP recipes have very specific limits on mass and water, the remaining water must be divided between the other hydroxide solutions. This results in having to make stronger solutions of sodium and potassium hydroxides to maintain the water balance. Unfortunately, making higher concentrations of sodium and potassium hydroxide produce solutions that freeze at near ambient conditions. In climates north of 30 degrees latitude, the caustic solutions could easily freeze in winter months. A method to preserve the water balance and make weaker solutions of sodium and potassium hydroxide is to remove water at some step in the mixing process. This would involve energy intensive unit operations, such as evaporators or other heating or flash vacuum units that would add equipment, complexity and expense to the system. This technique was rejected. However, substituting solvents other than water for the dissolution of sodium and potassium hydroxides provides another method of making weaker hydroxide solutions without exceeding water balance constraints. Using this technique, precipitation must be avoided by altering concentrations and the actual order in which the individual solutions are mixed.

Based on the analysis above, it was decided that resources would be better spent developing a design that can allow for peroxide to be added to solid hydroxides and remove heat in more plug flow type system configuration while still maintaining elements of the batch tank system. Such a design was created for the lithium hydroxide system. In fact, any of the hydroxide species can be substituted and analyzed for performance, but the lithium hydroxide solids offer the advantage of being small and not readily absorbing water from the atmosphere. Therefore, the lithium hydroxide mixing module will provide a test skid able to:

1. Compare different methods of introducing and mixing solids with liquids (possibly liquids other than water)
2. Compare the difference between exchanging heat using heat exchange elements versus performing heat exchange directly in the mix tank using internal coils.

The air deployable caustic production system was divided into modules that will accommodate transport aboard cargo planes. Each module (or skid) will have quick connect power and communication leads from a central power and control station. The modular concept will satisfy the transportability requirements and assembly constraints placed upon the system and compliment the addition of a system design for MHP production.

Since the final MHP product is sensitive to heat and contamination, the MOH production equipment selection was made with these constraints in mind. A chilling system, which is critical for process modules as well as product storage, was sized to provide the necessary cooling in the MOH tank. In addition, most of the equipment has been designed to reduce as much as possible or eliminate contaminants from the outside environment. Where possible, magnetically driven pumps have been used or pumps have been selected having seals that prevent incompatible fluids from entering the system. Mixer design has been scrutinized to prevent seal material from wearing and falling into the mixing vessel. Even the dry material addition components have been designed, to the extent possible, with additional safeguards preventing outside dust and debris from entering the system. Because of the dry solids additions, there must be fittings that will routinely be connected and disconnected. System filters located in recirculation lines have been added for the final measure to reduce system contamination. Should peroxide solutions ever be introduced as a solvent into the dilution tanks, the use of filters must be avoided and additional temperature protection loops must be added to each tank design.

Safety issues regarding the handling of alkali solutions were also addressed in the system design. Although a larger and more self-contained system would have neutralization and waste handling sub-systems, the SBIR request for proposal did not state this feature was required. However, the air deployable caustic mixing system does have provisions to neutralize system waste streams or unused product solutions. It does so by having convenient valves on the discharge side of all batch hydroxide mixing module pumps. Using these valves, fluid can be diverted to neutralization tanks provide by others. In addition, the MOH tank has a pump and valves capable of sending the solution to neutralization tanks provided by others. It is assumed the neutralization tank(s) will be at least 2,000 gallons in capacity, be equipped with a mixer, temperature control devices and be compatible with all hydroxides present in the system. It is further assumed that others will provide a source of phosphoric acid that will be metered into the tank. The presence of neutralization equipment will allow for a series of prototype testing occurring in a more efficient manner.

The MHP system is broken into subsystems. The following subsystems are represented on the Process Flow Diagram (PFD) 3160-FM-001 and the Piping and Instrumentation Diagrams (P&ID's).

3.3.2 Lithium Hydroxide Dilution:

The piping and instrumentation diagram (P&ID) 3160-F-001 represents the lithium hydroxide dilution module. In this part of the system, dry crystals of lithium hydroxide monohydrate are introduced into a tank and diluted with water. Heat of dilution is removed using either internal cooling coils or an in-line heat exchanger. The solution, when made to a predetermined strength, is pumped to the mixed hydroxide (MOH) tank.

SOLIDS HANDLING:
The lithium hydroxide skid makes use of a dry feed bulk bag unloading system. The bulk bag system was chosen since dry product is usually transported in "super-sacks". The bulk bag unloading frame comes with a hoist and trolley mechanism for lifting the bulk bags from grade to the dispensing position. It also is outfitted with bag massaging devices that ensures a significant amount of the dry product does not sequester to one corner of the bag and get choked off from the bag spout. In addition, the massagers help keep the material free flowing. Pneumatic slide gate valves will pinch the bag above the spout preventing solids from flowing out of the bulk bag until the bag spout is properly tied-off and sealed. The device that allows this to occur is an access box. The access box is closed and sealed after the bag connections have been made. The product is then released by opening the gate valves. This concludes the most "manual-intensive" operations of the system. The remaining steps can be accomplished by accessing a remote control display or be automatically performed in accordance with predetermined inputs.

The dry product flows through the spout but is stopped by a secondary disc-type valve mounted at the inlet of a receiver hopper. Once opened, the more automated material transfer operation begins. Dry product fills the hopper until a level or weight-sensing device closes the inlet disc-type valve again. The dry material is then discharged through an isolation disc-type valve mounted on the bottom of the hopper and fed into a centrifugal mixing system through a rotary valve. Setting the rotary valve rotation speed regulates the dry material flow into the mixer. This will continue until the loss-in-weight system reports that the solids have been dispensed. The final quantity will be reported and stored into the system programmable controller. The quantities of water necessary to make the final target concentration will be adjusted accordingly.

SOLID LIQUID MIXING AND EDUCTION DEVICE:
The lithium hydroxide inline mixing pump is a centrifugal eductor that causes suction at the 1-1/2" solids inlet port by circulating solution or water through the mixing head. The impeller provides the pumping action and includes design features that help grind and mix the solids into the circulating solution. Since the port is only 1-1/2", the lithium hydroxide crystals with maximum particle size of 850 microns were considered to be most suitable. Flake sizes of sodium and potassium hydroxides approach dimensions larger than ¾". These might prove to

be more difficult to feed without clogging problems. In addition, lithium hydroxide monohydrate will not adsorb water as readily as the other solids.

FLUID OVERFLOW CONTROL FOR INLINE MIXING PUMP:
Flow switches and high-pressure alarms are used to ensure the positive displacement pump is not dead-headed due to operator error or system fouling. The flow switch will also be interlocked to the solids mixing device ensuring that the positive displacement transfer pump is operating and circulating fluid prior to the mixer being activated. The three control valves regulating flow from or bypassing flow to the in-line mixing pump are also interlocked to prevent fluid from traveling up through the rotary valve. This is a possibility should the lithium hydroxide inline mixing pump loses its suction while an open path exists to the dilution tank. Therefore, start-up and shutdown sequencing for the inline mixing pump and valve sequencing is critical. Valves should have spring return fail closed positioned such that liquid flow is prevented from entering the in-line mixing pump should power or pneumatics ever fail.

IN-LINE HEAT EXCHANGE OPTION:
Once the solids have mixed with the circulating water, heat begins to be generated. The lithium hydroxide transfer pump circulates the mixture through a filter apparatus that will be manually by-passed at the start of all hydroxide solution sequences. This will prevent partially dissolved solids from fouling the line and causing overpressure scenarios. The mixture will then flow through the return circulation loop back to the dilution tank. The mixture can either by-pass or flow through an in-line heat exchange module. The heat exchange module can be specially designed to allow solids to pass through without fouling while static mixers create enough turbulence to bring the mixture into contact with the cool walls of the unit. This exchanger is a jacketed tube type exchanger with the benefit of having internal static mixing elements. One disadvantage is that the unit does take up a large amount of area compared to conventional shell and tube exchangers and much more room than plate & frame exchangers. Alternatively, shell & tube type exchangers can be used provided the tubes have sufficient internal diameters that allow passage of the dry solids. For lithium crystals, ½" to ¾" tubes are recommended. The plate & frame type exchangers risk significant fouling and blockage problems until all the dry material dissolved. By that time, local hot spots will likely accelerate corrosion.

BATCH TANK COOLING WITH INTERNAL COILS WITH MIXING:
The heat can also be exchanged in the tank itself using internal coils combined with a mixer and a coolant that is controlled by a temperature feedback loop. The difficulty using coils is that heat transfer area is fixed for a specific transfer rate once the unit is fabricated. Should recipes be altered and more heat transfer is necessary, the coils prove to be difficult, if not impossible, to adjust in the filed. In-line heat exchangers, on the other hand, can be readily altered or added to the system as long as the system head does not exceed required minimum values.

THE SYSTEM PUMP SELECTION:
A progressive cavity, positive displacement pump was chosen to transfer the lithium hydroxide solution. This pump type can handle the combination of liquid and solid slurries that will be circulating through the pipes as the solids pass into solution. Seal-less magnetic drive centrifugal pumps with a special design allowing for the presence of small solids were investigated. These pumps also had a distinct advantage in that they had no seals that could avoid operational and maintenance problems. However, to increase the flexibility of the caustic mixing system, the ability to accept larger solid flakes became important to the pump selection. Due to the potential size and loading of solids in the beginning of a batch, fears increased that the cooling channels of modified magnetically driven pumps would be fouled leading to pump

failure. Therefore, in this case, pump selection was based on the ability to handle large amounts of solids.

SOLUTION BATCH SEQUENCING:
It is anticipated that the deionized water will be introduced into the tank first before any solids are introduced. The amount of water introduced into the tank will be a percentage (between 80 to 95 percent) of the water called for by the recipe. In this way, most of the water will be available for the dissipation of heat and allow for the maximum reduction of viscosity. When the predetermined amount of alkali hydroxide solids (in this case lithium hydroxide monohydrate) has been fed into the mixer, the dry feeding isolation valves will close and the rotary valve will lock into position. Dry instrument air will purge the space between the eduction mixer and the rotary valve to ensure humidity is removed. Control valves will ultimately be closed to and from the mixer preventing fluid from entering the mixing head followed by the mixer being de-energized. A by-pass valve will be opened allowing the newly mixed hydroxide solution to recirculate. If peroxide is substituted for water, appropriate venting must be included for all lines isolated during the batch process.

Once the temperature and density approach levels that are in accordance with the amount of water and solids dispensed, the remaining water, having been adjusted considering the actual amount of solids charged into the system, will be metered into the tank. The solution will continue to be pumped back to the tank until all temperature and density readings attain suitable values. A sample port has been added where a small amount of fluid can be withdrawn and sent to a field laboratory for final concentration measurements.

When all the material is ready for transfer, the filters will no longer be by-passed. In this way, small contaminants can be removed prior to being mixed together with other hydroxide solutions in the MOH tank. As a precaution, a differential pressure indicator will signal if the filter becomes fouled.

TEMPERATURE CONTROL
A throttling flow control valve will control the coolant flowrate through the coils. The process variable, the reactor temperature reading, will be compared to a process set point. The difference the reactor temperature is away from the set point will determine the signal sent to open the temperature control valves TCV-0109A and TCV-0109B. When enough data has been collected to create a typical cooling curve, a control algorithm can be used to control the valve.

A similar cooling control strategy will also apply for the coolant flowing through the heat exchanger. Initially, the difference between the outlet temperature and the desired set point will dictate the control output and thus determine how open or closed the coolant control valve becomes. The process variable in this case is the outlet temperature of the solution heat exchanger.

SYSTEM & PUMP PROTECTION:
Each pump system also has strainers mounted on the discharge line of the dilution tank to protect the mixing pump and/or the progressive cavity transfer pump. It will also provide a spot where gross contamination such as tools, gloves, pens, etc., will be trapped.

DILUTION TANK FEATURES:
The top of the tank shall include a hand hole for manual additions of solids if required. A pressure control valve will be present on the dilution tanks allowing for normal venting and suction that accompanies pumping and filling operations. For this reason, there should be a filter installed on the

inlet side of the conservation vent preventing airborne contaminants from entering the system. This would be particularly important if hydrogen peroxide solutions were substituted for water.

ALTERNATE INLET PORT FOR DRUM EDUCTION SYSTEM:
All hydroxide dilution tanks will be outfitted with a side-mounted nozzle containing a dip tube. The tube assembly will be a connection for a drum eduction transfer wand should only drummed dry solids be available. In this case the drum eductor and wand assembly and a weigh scale would be required. These items are not shown on the P&ID and are not included in the system design since they only provide an alternative emergency means to introduce solids into the mix tank. The final production design for a caustic production system to be used in theater should include such equipment.

OTHER INSTRUMENTS:
Instrumentation includes several smaller in-line and tank mounted devices that ensure the system performs as expected. A level detection device ensures the tank is not overcharged. As mentioned, mass flow meters measure the flow of water into the tank and the density of the final solution as it is circulated back to the dilution tank. Adequately sized V-notch ball valves can be adjusted to ensure adequate back-pressure exists on the piping system containing the mass flowmeters.

FINAL QA/QC CHECK
The circulation loop contains a specialty sample valve that can be used to extract a volume of solution and test it in a field lab. If all the tests fall within acceptable ranges, then the fluid will be pumped to the MOH tank in the order dictated by a pre-programmed sequence. Operators using a human-machine interface with the PLC will enter the addition sequence in the beginning of the batch. When the PLC controller demands that the alkali hydroxide solution be transferred into the MOH tank, valve CV-0114 will be opened and CV-0112 will be closed.

3.3.3 Potassium & Sodium Hydroxide Dilution:

The piping and instrumentation diagrams (P&ID) 3160-F-002 and 3160-F-003 represent the sodium and potassium hydroxide dilution modules. In each of these systems, dry flakes of alkali hydroxide are introduced into their respective tanks and diluted with water. Heat of dilution is removed using internal cooling coils. The solutions, when made to predetermined strengths, are pumped to the mixed hydroxide (MOH) tank.

SOLIDS HANDLING:
The sodium and potassium hydroxide skids also make use of a dry feed bulk bag unloading systems. The bulk bag system was chosen since dry product is usually transported in super-sacks. The bulk bag unloading frame comes with a hoist and trolley mechanism for lifting the bulk bags from grade to the dispensing position. Both units are outfitted with bag massaging devices that ensures a significant amount of the dry product does not sequester to one corner of the bag and get choked off from the bag spout. In addition, the massagers help keep the material free flowing. Pneumatic slide gate valves pinch the bag above the spout preventing solids from flowing out of the bulk bag until the bag spout is properly tied-off and sealed. The device that allows this to occur is an access box. The access box is closed and sealed after the bag connections have been made. The product is then released by opening the gate valves. The remaining steps can be accomplished by accessing a remote control display or be automatically performed in accordance with predetermined inputs.

Both dry products flow through bag spouts. Secondary disc-type valves, mounted on the inlets of the receiver hoppers, regulate material flows. Once opened, the more automated material transfer operation begins. Dry product fills the hopper until a level or weight-sensing device closes the inlet disc-type valve. The dry material is then discharged through an isolation disc-type valve mounted on the bottom of the respective hopper and fed into a rotary valve. The dry material is then fed into the respective dilution tank using a rotary valve. Setting the rotary valve rotation speed regulates the dry material flow into the mixer. This will continue until the loss-in-weight system reports that the solids have been dispensed. The final quantity will be reported and stored into the system programmable controller. The quantities of water necessary to make the final target concentration will be adjusted accordingly.

Note that in the case of both potassium and sodium hydroxides, the bulk bag assembly has been raised. To prevent the introduction of other intermediate equipment, gravity feed was chosen to deliver large flake or crystalline raw material into the tank. A gate valve mounted on the inlet nozzle of the tank will close after all transfers are complete to prevent humidity from traveling up the piping to the rotary valve. Excess humidity will be readily absorbed by these hydroxides and will ultimately cake and foul the transfer line. As in the lithium hydroxide skid, instrument air will be used as a barrier and flush gas to keep dry material transfer lines and the raw material as dry as possible.

BATCH TANK COOLING WITH INTERNAL COILS WITH MIXING:
The heat is exchanged in the tanks using internal coils combined with mixers and a coolant that is controlled by temperature feedback loops. The difficulty using coils is that heat transfer area is fixed for a specific transfer rate once the unit is fabricated. Should recipes be altered and more heat transfer is necessary, the coils prove to be difficult, if not impossible, to adjust in the field. In-line heat exchangers, on the other hand, can be readily altered or added to the system as long as the system head does not exceed required minimum values. Future spaces have been allocated for heat exchange modules. For the interests of this prototype system, the lithium hydroxide system can be used to test whether flake type solids will cause operational problems

SYSTEM PUMP SELECTION:
Positive displacement pumps were selected for the potassium and sodium hydroxide transfer pumps. This pump type can handle the combination of liquid and solid slurries that will be circulating through the pipes as the solids pass into solution. This pump is particularly suitable for the potassium and sodium solutions containing No. 2 size flakes, which can be as large as ¾".

SOLUTION BATCH SEQUENCING:
It is anticipated that deionized water will be introduced into the tank first before any solids are introduced. The amount of water introduced into the tank will be a percentage (between 80 to 95 percent) of the water called for by the recipe. In this way, most of the water will be available for the dissipation of heat and allow for the maximum reduction of viscosity. When the predetermined amount of alkali hydroxide solids (in this case potassium and sodium hydroxide flakes) has been fed into the tank, the dry feeding isolation valves will close and the rotary valve will lock into position. Dry instrument air will purge the space between the slide gate valve mounted on the tank nozzles and the rotary valve to ensure humidity is removed. If peroxide is substituted for water, appropriate venting must be included for all lines isolated during the batch process.

Once the temperature and density approach levels that are in accordance with the amount of water and solids dispensed, the remaining water, having been adjusted considering the actual amount of solids charged into the system, will be metered into the tank. The solution will continue to be pumped back to the tank until all temperature and density readings attain suitable values. A sample port has been added where a small amount of fluid can be withdrawn and sent to a field laboratory for final concentration measurements.

When all the materials are ready for transfer, the filters will no longer be by-passed. In this way, small contaminants can be removed prior to being mixed together with the hydroxide solutions already present in the MOH tank. As a precaution, a differential pressure indicator will signal if the filter becomes fouled.

TEMPERATURE CONTROL
A throttling flow control valve will control the coolant flowrate through the coils. The process variable, the reactor temperature reading, will be compared to a process set point. The differential between the reactor temperature and the set point will determine the signal sent to open the temperature control valves TCV-0109A/B. When enough data has been collected to create a typical cooling curve, a control algorithm can be used to control the valve.

SYSTEM & PUMP PROTECTION:
Each pump system also has strainers mounted on the discharge line of the dilution tank to protect the mixing pump and/or the progressive cavity transfer pump. It will also provide a spot where gross contamination such as tools, gloves, pens, etc., will be trapped.

DILUTION TANK FEATURES:
The top of the tank shall include a hand hole for manual additions of solids if required. A pressure control valve will be present on the dilution tanks allowing for normal venting and suction that accompanies pumping and filling operations. For this reason, there should be a filter installed on the inlet side of the conservation vent preventing airborne contaminants from entering the system. This would be particularly important if hydrogen peroxide solutions were substituted for water.

ALTERNATE INLET PORT FOR DRUM EDUCTION SYSTEM:
All hydroxide dilution tanks will be outfitted with a side-mounted nozzle containing a dip tube. The tube assembly will be a connection for a drum eduction transfer wand should only drummed dry solids be available. In this case the drum eductor and wand assembly and a weigh scale would be required. These items are not shown on the P&ID and are not included in the system design since they only provide an alternative emergency means to introduce solids into the mix tank. The final production design for a caustic production system to be used in theater should include such equipment.

OTHER INSTRUMENTS:
Instrumentation includes several smaller in-line and tank mounted devices that ensure the system performs as expected. A level detection device ensures the tank is not overcharged. As mentioned, mass flow meters measure the flow of water into the tank and the density of the final solution as it is circulated back to the dilution tank. Adequately sized V-notch ball valves can be adjusted to ensure adequate back-pressure exists on the piping system containing the mass flowmeters.

FINAL QA/QC CHECK
The circulation loop contains a specialty sample valve that can be used to extract a volume of solution and test it in a field lab. If all the tests fall within acceptable ranges, then the fluid will be pumped to the MOH tank in the order dictated by a pre-programmed sequence. Operators using a human-machine interface with the PLC will enter the addition sequence in the beginning of the batch. When the PLC controller demands that sodium hydroxide solution is to be transferred, valve CV-0214 will be opened and CV-0212 will be closed. For potassium hydroxide solution, final transfer involves opening valve CV-0314 and closing CV-0312.

3.3.4 MOH Make-up Tank:

P&ID 3160-F-004 illustrates the critical elements used for MOH production. Once individual alkali hydroxide solutions have passed appropriate quality checks, the three alkali solutions are pumped into this pre-chilled tank in a predetermined order. Additional water can be added to the tank to adjust the final MOH concentration. Chilling will be possible by circulating Syltherm 800 through coils and an external jacket at a temperature of approximately -13°F.

ALKALI HYDROXIDE SOLUTION ADDITION
The lithium, sodium and potassium hydroxide solutions can be pumped into the MOH tank in any pre-selected order. The mass of each alkali hydroxide can be totalized by flowmeters FT-0114, FT-0214 and FT-0314, respectively. When the set-points for each solution have been reached the control valves CV-0114, 0214 and 0314 will close and simultaneously valves CV-0112, 0212 and 0312 will be opened before the transfer pumps will be stopped.

WATER ADDITION
Any additional water necessary to achieve the final MOH solution concentration shall be added into the tank. The water will be totalized using flowmeter FT-0400. Restriction orifices are placed downstream of the mass flowmeters to ensure there is enough back-pressure to optimize the performance of the flowmeter. The resulting mixed alkali solution, known as MOH, will be recirculated and sampled for a quality check.

MOH HEAT EXCHANGE AND CHILLING
Temperature coils inside the tank control the temperature at or below 32°F (O°C) and remove residual heat of dilution. A throttling flow control valve will control the coolant flowrate through the coils and jacket. The process variable, the reactor temperature reading, will be compared to a process set point. The differential between the reactor temperature and the set point will determine the signal sent to open the temperature control valve TCV-0409. In addition, a mixer will be used to ensure the alkali solutions are rapidly mixed together and will provide convection for heat transfer. The final MOH solution will be circulated through a loop back to the MOH tank. A mass flow meter will measure the density of the final solution prior to transferring the product to a user, another storage vessel or to a neutralizer tank supplied by others. In addition, manual samples may be drawn from the circulation loop and analyzed before pumping the fluid to a potential user.

MOH TANK CAPACITY, DESIGN PRESSURE AND MATERIAL CONSIDERATIONS
The MOH Make-up tank volume of 1,640 gallons is larger than the design volume of 1,100 gallons. This allows for variances in batch volume and for freeboard for mixing. In addition, the volume is larger so that it can serve as a MHP tank in future applications.

The tank design is also suitable to withstand some degree of internal pressure accumulation from rapid decomposition. Therefore, the heads will be ASME dished heads and the wall thickness will be designed to withstand full vacuum and up to 60 psig internal pressure.

The MOH tank is to be made of 316L SS to prevent corrosion from the cool alkali hydroxide mixture. Gasket material will be PTFE. The MOH tank was fitted with the appropriate relief devices should it be combined with a peroxide mixing system. In this scenario, the tank can serve as either a MOH mixing tank or a MHP mixing tank. Also, under these same circumstances, the wetted parts can be pickled and passivated for peroxide applications.

SAFETY RELIEF DEVICES FOR OTHER APPLICATIONS

In order to further increase the usefulness and adaptability of the caustic mixing system, the MOH tank was designed to allow for the introduction of concentrated high purity hydrogen peroxide. Two safety relief devices are present on the tank. One device acts as a low-flow breather and allows oxygen to escape from the tank. The unit is packed with a fine granular material that prevents contamination from entering the tank. The second relief device is a safety measure in the unlikely event a rapid decomposition reaction takes place. This device consists of a man-way lid on guides and will lift off of its seat should the pressure rise suddenly. With minimal upgrades or module additions, the MOH tank can serve as a peroxide mixing tank. By adding other system upgrades, an inexpensive MHP test system can be constructed to test heat transfer and production capabilities. A conservation vent permits normal volume gas flows, from filling and pumping operations, to occur.

THE MOH MAKE-UP TRANSFER PUMP

The MOH product will also be circulated using a magnetic drive pump capable of circulating small solids. Here, solids and precipitation are considered to be minimal. Use of a magnetic drive pump offers extra protection against contamination entering the process since there are no seals.

3.3.5 The Deionized Water Module

P&ID 3160-F-005 illustrates the primary components of the process deionized (DI) water system. In this design, the feed water source will originate from the local potable water supply. It is assumed that this water will conform to Federal primary drinking water standards. The conductivity measurements of the water and the concentration of ions that decompose peroxide shall be used as criteria to determine final water quality acceptance. It has been assumed that process water having a conductivity of at least 25 μmhos and TDS concentrations in the parts-per-billion range will suffice for this system. The flow rate of process water required would be very small depending on the strengths of the alkali solutions introduced into the alkali hydroxide and MOH modules. The potable water demand will be designed for 10 gpm (38 lpm) since holding tanks will fill at a reasonable rate.

The system will be comprised of a pre-filter, an activated carbon filter, two resin bed filters, and a post treatment filter. It shall possess the necessary conductivity instrumentation and controls and necessary pressure regulation controls required for normal system operation. It is not the intention of this system to re-use water after MOH solutions have been neutralized by others, chemically treated and filtered.

Once the water passes through the DI filtration unit, the process water is collected in a 2,000-gallon (7570 liter) tank. P&ID F-005 shows there are two pumps connected to the water storage tank. One is called the de-ionized water transfer pump and is used to feed water to the alkali hydroxide dilution tanks and the MOH Make-up tank. The water is metered to the tanks using mass flowmeters and totalizers. The other pump is the de-ionized water wash pump. This larger pump has more power and shall be used to send process water to clean-in-place spray ball heads inside of most of the tanks. The water will only be used for cleaning purposes and as a part of the decontamination procedure prior to disassembly operations. Back-pressure regulators are used to ensure water can return to the DI water tank when users fall from the system.

3.3.6 The Cooling System

The closed loop cooling system, as depicted on P&ID 3160-F-006 provides sufficient cooling to remove heats of dilution in the alkali hydroxide tanks and to maintain MOH solution at or below 32°F (O°C) in order to prepare it for use in a future MHP system.

The package chiller unit supplies approximately 100 tons of refrigeration, using R-22 as a refrigerant to chill the process cooling fluid, Syltherm 800. Syltherm 800 was chosen because it does not react with hydrogen peroxide and peroxide solutions.

The major components of the package system are:

- Screw compressor package with electric motor drive, oil cooler, oil filter and microprocessor controls.
- Air-cooled condenser capable of condensing at 120°F (49°C) and providing 2,100,000 BTU/hr cooling capacity when ambient temperatures are around 95°F (35°C).
- High pressure receiver
- Economizer – shell and tube direct expansion type to sub-cool condensed liquid refrigerant
- Evaporator – shell and tube direct expansion type to cool Syltherm 800 from 1°F to -13°F
- Piping, to interconnect the components listed above
- Electrical components, includes motor starters, wiring and microprocessor controls
- Structural steel skid to hold assembly of above listed components

3.3.7 Plant Air System

A properly-sized air compressor/air receiver package, desiccant air dryer and filter will be provided to supply instrument–quality air for control valves and other uses. The system is represented on P&ID 3160-F-007. Final equipment sizing will occur during a detailed engineering (Phase II) effort after all instrument and process air requirements have been tabulated.

3.3.8 Neutralization

Others will provide the tanks, pumps, instruments, controls and chemicals used to neutralize the unused alkali hydroxide solutions during testing. Phosphoric acid is recommended to neutralize unused batches of MOH or alkali hydroxide solutions, off-spec batches of alkali material and contaminated wash water. Phosphoric acid should be chosen because it has more than three available hydrogen atoms for donation to the neutralization process. This reduces the moles of acid required for neutralization relative to other selections such as hydrochloric acid (HCl). In addition, phosphate salts of some alkali cations such as lithium are insoluble over specific pH ranges. This may be used in subsequent separation steps to remove lithium from the waste stream and reduce the amount of solid waste that must be treated and ultimately disposed of.

3.4 The Equipment Arrangement Drawings:

The general arrangement of each skid is represented in drawings 3160-A-001 and 3160-A-002. In heavier line weights, the skids representing the air transportable caustic mixing system, the topic of this SBIR sponsored project, is shown. The lighter line weights represent system skids that were presented in the air-transportable mixed base hydrogen peroxide mixing system proposed under a former SBIR topic. The arrangements clearly show how other system elements would be arranged to provide for a complete MHP production system. Since the capacities are nearly complementary, this would represent a mobile chemical mixing plant capable of making MHP in theater for the air-borne laser program. Neutralization and recycled water systems are not included in this overall design, but could be added as auxiliary skids.

On the left of drawing 3160-A-001 are three alkali hydroxide bulk bag dispensing frames and the batch alkali hydroxide dilution tanks. Note the top left assembly. The lithium hydroxide skid has two interconnecting arrows that represent piping between the skids. This piping represents the connection between the dilution tank and the in-line solids mixing pump located beneath the bulk bag loading system. Note also the skid above the lithium hydroxide dilution tank. A large heat exchange skid is shown that is able to pass solid slurry mixtures and remove the heat of dilution without fouling. Alternatively, since the crystals of lithium hydroxide are small, a second shell and tube type heat exchange is shown mounted directly onto the lithium hydroxide skid. It is shown on the right side of the dilution tank and in the center of the skid. Final selection of which heat exchanger shall be used in subsequent development will be based on process considerations and economics during the detailed engineering phase of development. Both types of exchangers appear as options in the equipment list.

All piping converges on assembled rack supports to the MOH make-up skid shown in the center of 3160-A-001. Deionized water skids and the MOH chiller module are also represented. The chilled solution pump frame would have to be located in an interim position prior to the MHP modules being added to the MOH skids. This interim pump support frame would be located where the acid storage system module is shown.

3.5 The Electrical Single Line Diagrams:

The electrical single line diagrams are shown on drawings 3160-E-001 and 3160-E-002. The electrical supply is a 750 KVA transformer provided by others capable of accepting portable TYPE G 3C-350 KCMIL power cables. The power enters a main switchboard located in a main control and power distribution skid. All individual skids will be connected to the main switchboard using 4C#4 or 4C#8 portable cords with quick disconnect NEMA 4X plugs. Therefore, each skid will have its own local MCC and control panel. Since each skid has only a single power cable with quick disconnect plugs, time required for field wiring is reduced during assembly. Signal cables, not shown, will have the identical design philosophy.

Note that the chiller system pump skid contains a future H-805 heater fan. This unit was added as a possible contingency if the coolant is too cold and causes local freezing on the surface of heat exchange cooling coils. The equipment information is listed on the attached equipment list for reference. However, the unit does not appear on any arrangement or piping drawing.

ELECTRICAL CONSIDERATIONS RESULTING FROM THE INTEGRATION OF THE CAUSTIC SYSTEM WITH AN MHP MIXING SYSTEM

It is the intent of this design to accommodate the addition of skids to form a complete MHP system in the future. The electrical requirements to do so were examined. It is suggested that two separate transformers be provided by the responsible government agency to best meet this objective.

The caustic system will have a maximum connected load of 619.5 kVA with an assumed demand of 90%. This will require a 750 kVA pad mounted transformer furnished by others. The 480V – 3 phase MCC will be equipped with a 900 Ampere main breaker with 65,000 Ampere interrupting capacity (See drawing 3160-E-001). One option would be to furnish a 500 kVA transformer at 110% overrate with a 700 Ampere main breaker fed by a parallel 500 kcmil cable. This would offer a slight cost advantage over the 750 kVA transformer options. The provider of the power source can make their final determination based on their constraints.

The previously designed MHP system will have a maximum connected load of 723.5kVA with an assumed demand of 90%. This will require a 750kVA pad mounted transformer furnished by others. The 480 – 3 phase MCC will be equipped with a 900 Ampere main breaker with 65,000 Ampere interrupting capacity.

The feasibility of supplying a single common 1500 kVA pad mounted transformer was investigated. However, if one system were installed without the other, increased short circuit current and ground fault requirements would require more costly equipment. Also, individual services offer greater flexibility for a project with dynamics such as this.

To maintain flexibility, it is recommended that the caustic mixing system have a dedicated 750kVA (or 500kVA) power supply and that a MHP system also have an independent 750kVA transformer.

4.0 THEORETICAL SYSTEM ACCURACY REVIEW

The caustic mixing system has several measuring devices to accurately meter solids and liquids into the relevant tanks. In the final tank, the mixed alkali hydroxide solution (MOH solution) must have error no larger than 0.5% of the theoretical target recipe weights. In order to demonstrate that our system components meet this requirement, the following analysis is provided.

The following analysis considers the accuracy of the proposed load cells (BLH model SBP1 shear beam cells) used in the dry material dispensing units and the Coriolos mass flow meters (Endress Hauser Promass 80/83) used to dispense water.

LOAD CELL ERROR ASSOCIATED WITH SOLIDS DISPENSING UNIT:
For the load cells, the maximum error is the cumulative error multiplied by the system capacity. The load cell cumulative error applies for the entire load cell system. That means that if the bulk bag unloading system weighs 10,000 lbs. (4536 kg), the total cumulative error would be:

Error = (Cum. Error %) * (System capacity lbs.)/100

Therefore, the maximum error for the load cells is easily calculated if the system weight is known. In our design we have assumed that the portions of the bulk bag frame that will be weighed plus the bulk bag (2000 lbs. or 907 kg) will weigh a maximum of 10,000 lbs (4536kg). The cumulative error is listed as 0.05% so using the equation above, the maximum error is 5 lbs per unloading system. The contribution from the various modules is shown in Table 4.1.

TABLE 4.1
ERROR ANALYSIS FOR LOAD CELLS

Description	NaOH	KOH	LiOH H_2O	Water
lb/batch	2042	2050	1045	0
Total Capacity of Solids System lbs	10,000	10,000	10,000	10,000
Cum Error (%)	0.05	0.05	0.05	0.05
±Error (lb) = Capacity * Cum. Error/100	5	5	5	0

MASS FLOW METER ERROR ASSOCIATED WITH WATER ADDITIONS:
Water is introduced into all of the dilution tank modules. Naturally, there is error associated with each device. For the selected 1-1/2" flowmeters, the rated zero point stability is 0.083 lb/min (2.25 kg/hr). The calculation for the maximum measured error for Promass "F" or "M" tubes and Series 80 transmitter combinations is:

$$\text{Error} = \pm 0.15\% \pm [(\text{Zero point stability lb/min})/(\text{measured value lb/min})] * 100\% \pm \text{Temperature error correction } \% \pm \text{Pressure correction error } \%$$

The temperature correction and pressure correction calculations are documented in the flowmeter literature and are based on deviations from 0 psig and 70°F (21.1°C). For the pressure correction term, it was assumed that the flowmeter would be operating at a maximum pressure of 20 psig. Therefore, if the value listed for the Promass units "F" is 0.0002 %/psi for a 1-1/2" meter, the pressure error is equal to 0.004%.

Similarly, the temperature error factor is listed as 0.0001% full scale value / °F. If the worst temperature difference occurred it would be the difference between 40 °F and 70 °F or 100 °F and 70 °F. In any event, the temperature difference would be 30°F. That means an extra 0.003% of accuracy may be sacrificed at extreme water temperatures.

Table 4.2 lists the amounts of water used for each dilution tank and the final MOH tank. Since the zero point stability is expressed as a rate, the maximum error of each water addition is calculated using the flowrate of water through the meter. The resulting accuracy percentage is then multiplied by the target batch water delivery set point to determine the maximum expected error.

TABLE 4.2
ERROR ANALYSIS FOR MASS FLOWMETERS

Description	NaOH	KOH	LiOH H_2O	Water
Capacity lb/batch water	4534	2050	4624	28
Zero Point Stability	0.083	0.083	0.083	0.083
Flow (gpm)	75	75	75	75
Density of fluid (lb/gal)	8.345172	8.345172	8.345172	8.345172
Flow (lb/min)	625.88	625.88	625.88	625.88
Max. Pressure Error %	0.004	0.004	0.004	0.004
Max. Temperature Error	0.003	0.003	0.003	0.003
Cum Error (%) Using Equation	0.1703	0.1703	0.1703	0.1703
±Error (lb) = Capacity * Cum. Error/100	7.72	3.49	7.87	0.048

MASS FLOW METER ERROR ASSOCIATED WITH ALKALI HYDROXIDE TRANSFERS TO THE MOH MAKE-UP TANK:
Alkali hydroxide solutions are metered in various proportions dictated by the MOH recipe into the MOH make-up tank. The error associated with each flow measuring device must be accounted for. Again, for system interchangeability, the selected flowmeters are identical to those used for water delivery. The analysis is the same as above. Table 4.3 lists the errors associated with the alkali hydroxide transfers.

TABLE 4.3
ERROR ANALYSIS FOR MASS FLOWMETERS

Description	NaOH	KOH	LiOH H_2O
Capacity lb/batch alkali hydroxide solutions	3288	2050	5669
Zero Point Stability	0.083	0.083	0.083
Flow (gpm)	75	75	75
Density of fluid (lb/gal)	11.0587	12.1044	9.88927
Flow (lb/min)	829.4	907.8	741.7
Max. Pressure Error %	0.004	0.004	0.004
Max. Temperature Error	0.003	0.003	0.003
Cum Error (%) Using Equation	0.1678	0.1669	0.1690
±Error (lb) = Capacity * Cum. Error/100	5.52	3.42	9.58

The summary of accumulated errors is given in the final Table 4.4. note that the grand total is compared to the maximum error allowed (0.5%) multiplied by the target system capacity of 11,036 lb/batch (5005 kg/batch), which is ±55.2 lb/batch (±25 kg/batch).

TABLE 4.4
CUMULATIVE ERROR ANALYSIS

System	Water Flowmeter Error (± lbs.)	Alkali Hydroxide Flowmeter Error (± lbs.)	Solids Load Cell Error (± lbs.)	Total Error (± lbs.)
NaoH	7.72	5.52	5	18.24
KOH	3.49	3.42	5	11.91
LiOH – H_2O	7.87	9.58	5	22.45
Water	0.048	0	0	0.048
TOTAL CUMULATIVE ERROR (lbs)				52.64

Therefore, the cumulative propagation of theoretical errors resulting in a final batch error at or within ±52.6 lbs (±23.9 kg) listed in Table 4.4 demonstrates that the total maximum error falls within the specified accuracy set forth in the SBIR requirements.

5.0 MATERIAL SELECTION FOR CAUSTIC SYSTEM EQUIPMENT AND MATERIAL OPTIONS

Several different materials exist to contain the alkali hydroxide solutions represented in this system design. The materials selected were chosen on the basis of chemical compatibility, availability and economics. The last two criteria listed do not always lead to the same selection over time. For this reason, this section lists some alternatives for tank materials, pump housing and impeller materials, seal materials for gaskets and o-rings, filter media materials and piping materials.

Alkali hydroxides are extremely corrosive, particularly at elevated temperatures. Fortunately, the caustic production system does not need to consider temperatures above ambient conditions for typical operations. However, there are circumstances where localized temperatures may reach the boiling point of water or higher if cooling is not readily available during dilution operations. Therefore, the designer must be careful when choosing materials that could be exposed to these local hot spots.

Table 5.1 reviews several different metals used for tank, pipe, valve, pump casing and other housing construction. Note that concentration and the type of alkali hydroxide have impacts on the corrosion rate and the acceptable temperature range.

Carbon steel is used to transfer up to 50% solutions of NaOH and KOH, but the temperature range drastically falls off when concentrations approach 50% NaOH or KOH. In the case of KOH, carbon steel is an unacceptable selection if exposed to concentrations above 50%. Using mild carbon steel (and iron) also requires a passivation treatment prior to placing the material into service. The passivation procedure involves spraying 5% to 20% caustic solutions onto the metal at temperatures falling at 100°F to 140°F. The caustic mixing system cannot tolerate contaminants such as iron because subsequent systems used for MHP production cannot tolerate the iron contamination. Therefore, carbon steel should be rejected as a possible material.

High silicon iron is also used in industrial facilities to off-load 50% NaOH solutions. It is listed as satisfactory and has a narrow temperature range when compared to nickel alloys or 316 SS. No doubt this would be an economic selection if temperatures remain low and corrosion products can be tolerated by the system in question. High silicon iron does not have a broad temperature range when exposed to 50% KOH.

Nickel or Nickel containing alloys such as Hastelloy-C has superior corrosion resistance over relatively high temperatures. In the case of Nickel, NaOH causes the material to be vulnerable to stress cracking. Alloy 20Cb3 performs well but seems to be susceptible to stress cracking when exposed to NaOH concentrations 30% to 50%.

Of the stainless steel found in the literature, 316SS offers the most resistance over the largest temperature range for both NaOH and KOH. Unlike 304SS or 307SS, 316SS seems to be prone to stress cracking at NaOH concentrations around 50%. All stainless steels considered seem prone to stress cracking when exposed to KOH solutions.

TABLE 5.1
COMPATIBILITY OF NaOH & KOH WITH METALS

METAL	SPECIES	CONC. MASS % SOLN.	APPROX. TEMP RANGE (°F)	RATING Mils penetration/year	NOTES
Carbon Steel	NaOH	10	60-210	<20-Good	
	"	30	60-210	<20-Good	
	"	50	120 max	<50-Satisfactory	Note 1
	KOH	5	60-210	<20-Good	Note 3
	"	27	60-190	<20-Good	Note 3
	"	50	60-80	<20-Good	Note 2,3
Hastelloy C	NaOH	10	60-220	<20-Good	
	"	30	60-200	<20-Good	
	"	50	60-140	<2-Excellent	
	"	"	140- 180	<20-Good	
	KOH	5	60-200	<20-Good	
	"	27	60-200	<20-Good	
	"	50	60-200	<20-Good	
Nickel	NaOH	10	60-200	<20-Good	Note 3
	"	30	60-300	<20-Good	Note 3
	"	50	60-220	<2-Excellent	Note 3
	"	"	220-280	<20-Good	Note 3
	KOH	5	60-200	<2-Excellent	
	"	27	60-200	<2-Excellent	
	"	50	60-220	<2-Excellent	

*Most of the data was taken from Schweitzer, Philip A., "**Corrosion Resistance Tables Metals, plastics, non-metallics and rubbers, 2nd Edition**", Marcel Dekker, Inc., NY*

TABLE 5.1 Continued
COMPATIBILITY OF NaOH & KOH WITH METALS

METAL	SPECIES	CONC. MASS % SOLN.	APPROX. TEMP RANGE (°F)	RATING Mils penetration/year	NOTES
316 SS	NaOH	10	60-340	<2-Excellent	
	"	30	60-160	<2-Excellent	
	"	"	160-200	<20-Good	Note 4
	"	50	60-160	<2-Excellent	Note 3
	"	"	160-340	<20-Good	Note 3
	KOH	5	60-340	<20-Good	Note 3,5
	"	27	60-340	<20-Good	Note 3,5
	"	50	60-340	<20-Good	Note 3,5
304/307 SS	NaOH	10	60-200	<2-Excellent	
	"	30	60-160	<2-Excellent	
	"	"	160-200	<20-Good	
	"	50	60-160	<2-Excellent	
	"	"	160-200	<20-Good	
	KOH	5	60-200	<20-Good	Note 3
	"	27	60-200	<20-Good	Note 3
	"	50	60-200	<20-Good	Note 3
Alloy 20Cb3	NaOH	10	60-200	<2-Excellent	
	"	"	200-290	<20-Good	
	"	30	60-120	<2-Excellent	Note 3
	"	"	120-290	<20-Good	Note 3
	"	50	60 290	<20-Good	Note 3
	KOH	5	60-200	<20-Good	
	"	27	60-200	<2-Excellent	
	"	50	60-200	<20-Good	
High Silicon Iron	NaOH	10	60-100	<20-Good	
	"	10	100-160	<50-Satisfactory	Note 6
	"	30	60-140	<50-Satisfactory	Note 7
	"	50	60-140	<50-Satisfactory	Note 7
	KOH	5	60-100	<2-Excellent	Note 8
	"	27	60-180	<20-Good	Note 9
	"	50	60-100	<50-Satisfactory	

1. *Unsatisfactory at higher temperatures but at higher concentrations, carbon steel remains satisfactory up to 220°F and beyond.*
2. *Unsatisfactory above 80°F and same applies at higher concentrations.*
3. *Material is subject to stress cracking*
4. *Unsatisfactory above 200°F*
5. *Unsatisfactory above 340°F*
6. *Unsatisfactory above 160°F*
7. *Unsatisfactory above 140°F*
8. *No data beyond 100°F*
9. *Unsatisfactory above 180°F*

Metals to be avoided are aluminum, copper, zinc, lead and alloys of these metals such as brass and bronze. Both NaOH and KOH solutions in the concentrations used in the caustic mixing system readily attack these materials.

In summary, the most economical selections that do not introduce significant amounts of iron into the caustic mixing system appear to be 316SS and Alloy 20 and other nickel alloys. They make ideal tank materials. Heat exchange coils that are difficult to service should be made of the more resistant materials if possible. Since the proposed system is a prototype, 316L SS should meet the necessary requirements and not contaminate the solutions significantly.

Regarding non-metallic materials used for filter media, seals, piping liners, pump components and possibly piping systems, Table 5.2 summarizes the materials that prove to be resistant.

TABLE 5.2
COMPATIBILITY OF NaOH & KOH WITH NON-METALS

NON-METAL	SPECIES	CONC. MASS % SOLN.	APPROX. TEMP RANGE (°F)	RATING	NOTES
Nitrile Buna-N	NaOH	0-50	60-140	Resistant	
	KOH	50	60-140	Resistant	Note 1
Carbon	NaOH	0-50	60-250	Resistant	
	KOH	0-50	60-330	Resistant	
CPVC	NaOH	0-50	60-180	Resistant	
	KOH	0-50	60-180	Resistant	
EPDM	NaOH	50	-	-	No data
	KOH	50	-	Resistant	
FRP	NaOH	0-50	-	Resistant	Note 2
	KOH	0-50	-	Resistant	Note 2
Hard Rubber	NaOH	0-50	60-180	Resistant	
	KOH	0-50	60-180	Resistant	
Natural Rubber	NaOH	0-50	60-140	Resistant	
	KOH	0-50	60-100	Resistant	
Polyethylene	NaOH	0-50	60-140	Resistant	
	KOH	0-50	60-140	Resistant	
Polypropylene	NaOH	0-50	60-200	Resistant	
	KOH	0-50	60-170	Resistant	
PVC Type 1	NaOH	0-50	60-140	Resistant	
	KOH	0-50	60-140	Resistant	
Teflon® or TFE	NaOH	0-50	60-450	Resistant	
	KOH	0-50	60-450	Resistant	
Viton Type A	NaOH	0-50	60	Resistant	
		0-50	Temp >60	Not Satisfactory	
	KOH	50	-	Not Satisfactory	
		0-30	60-80	Resistant	

1. *Buna-N is unacceptable for KOH concentration less than 50%*
2. *FRP interior surface in contact with NaOH or KOH solutions should have a resin rich layer*
3. *Most of the data was taken from Schweitzer, Philip A., "**Corrosion Resistance Tables Metals, plastics, non-metallics and rubbers, 2nd Edition**", Marcel Dekker, Inc., NY*

In general, there are few non-metals that hold up against the conditions the caustic mixing system will impose. Fluorocarbons such as polytetrafluoroethylene (TFE) or perfluoro (ethylenepropylene) co-polymer (FEP) have the best resistance and the broadest temperature range over the concentrations identified. Even a TFE such as Teflon® has limitations when cooled. It may shrink at lower temperatures that are seen later in the MHP process. However, for caustic mixing, it is perfectly acceptable.

Chlorinated polyvinyl chloride (CPVC), Hard Rubber and Polypropylene show resistance over elevated temperatures (170 °F to 200 °F). The upper temperature limits are a function of the materials being considered. CPVC can be used as an inexpensive piping material, however its lack of strength from impact makes this selection dubious. In view of the rapid assembly requirement, piping materials must be robust and be able to handle a certain amount of abuse. The lack of integrity and susceptibility to UV light also raises safety issues. All these materials share this handicap to one degree or another. Nevertheless, the materials listed can serve as liner materials as long as the materials are not placed in a heat transfer application.

FRP, or fiber-reinforced plastic, has chemical resistance and can sustain temperatures beyond 180°F. The only difficulty with using FRP is that resins will contaminate the caustic solutions and may have unacceptable consequences when MHP is made using higher strength hydrogen peroxide.

Materials such as polyethylene, polyvinyl chloride (PVC Type 1) and natural rubber have lower temperature ranges making them less useful.

Regarding seal material, Ethylene propylene rubber (EPDM) might prove to be an elastomer capable of being used. It is rated highly resistant in various chemical resistance charts for NaOH and KOH, but caution should be exercised in view of the lack of data for NaOH at 50%. Teflon enveloped silicon is a good gasket material. Buna-N can also be used provided the temperatures are not above 140 °F.

Materials to be avoided are Viton, Nylon, Ryton (for NaOH only), Kynar (for 50% solutions), Neoprene, silicone (at higher temperatures), polybutadiene, vinyl esters, isophthalic resins, chlorinated polyesters and glass.

6.0 REFERENCES

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2. Hurley, Jim A., AFRL/MLQL: 2002, "Surrogate MHP Formulation", SBIR solicitation Supplement

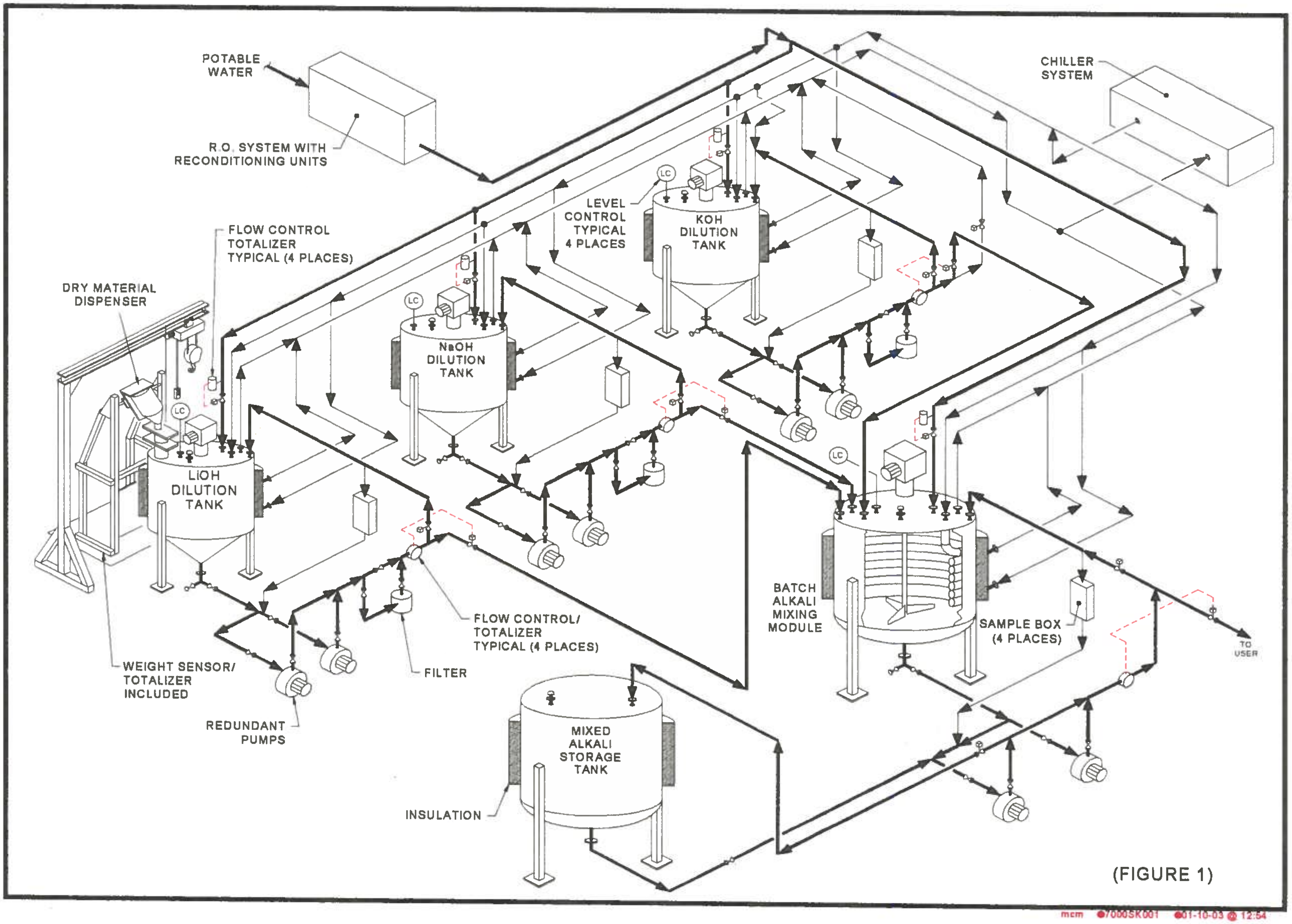
3. Missile Defense Agency: 2002, "Air-transportable, Rapid Production Mixed-base Hydrogen Peroxide System", SBIR solicitation

4. Occidental Chemical Corporation: 1995, "Caustic Soda Handbook", Oxychem, Dallas TX

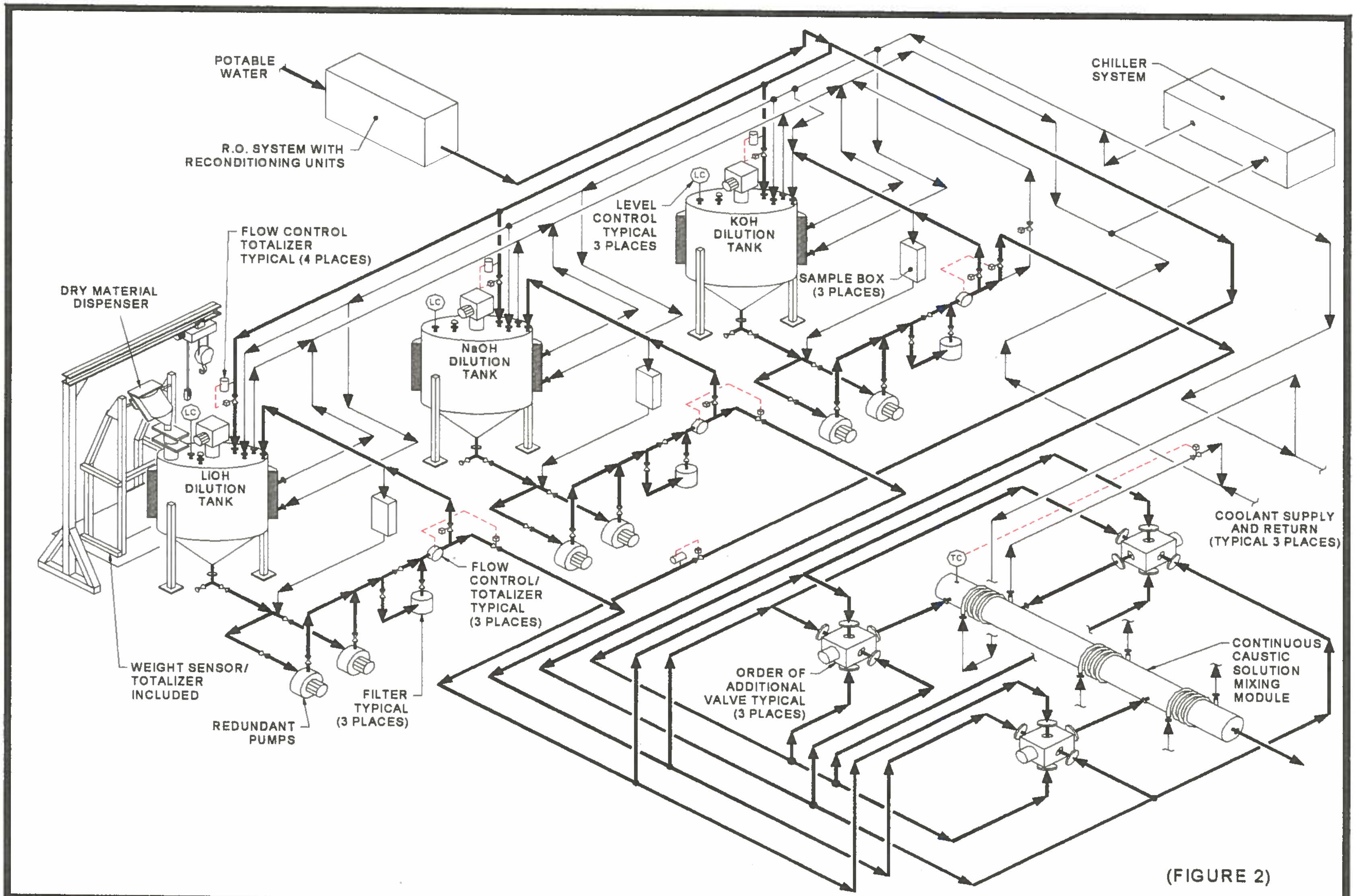
5. Occidental Chemical Corporation: 1995, "Caustic Potash Handbook", Oxychem, Dallas TX

6. Schweitzer, Philip A., "Corrosion Resistance Tables Metals, plastics, non-metallics and rubbers, 2nd Edition", Marcel Dekker, Inc., NY

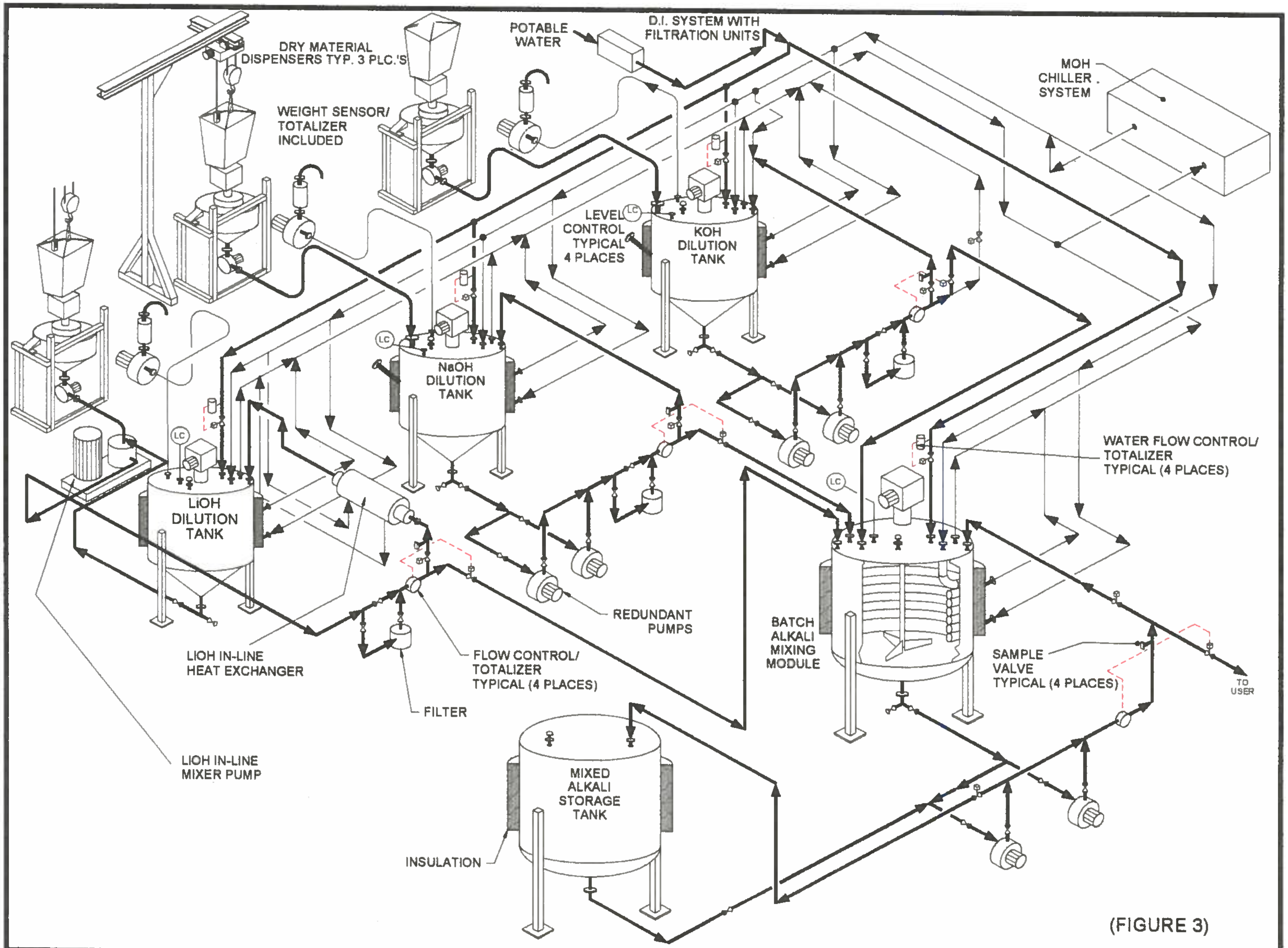
APPENDIX A FIGURES



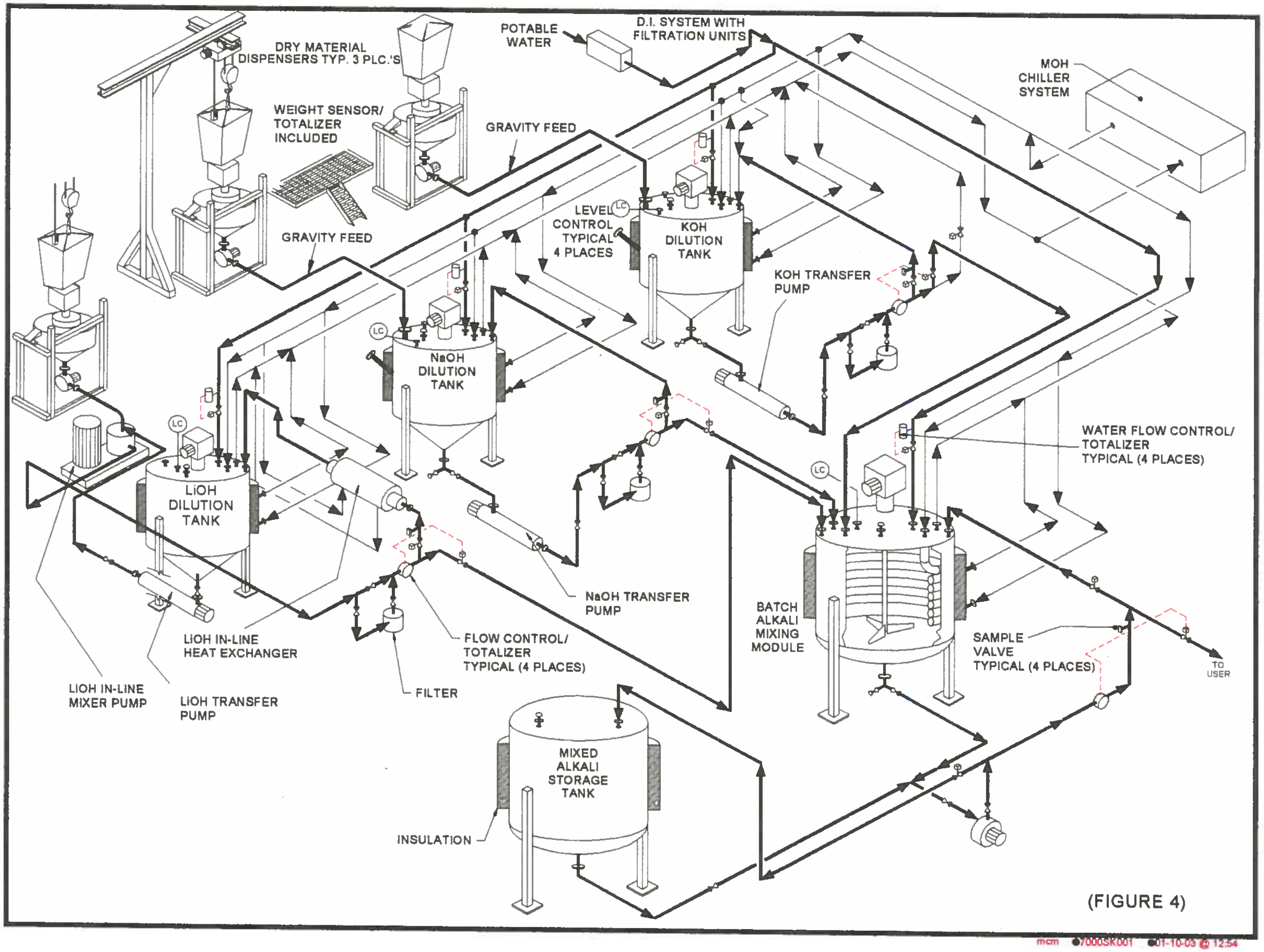
(FIGURE 1)


POTABLE WATER
R.O. SYSTEM WITH RECONDITIONING UNITS
CHILLER SYSTEM
LEVEL CONTROL TYPICAL 3 PLACES
KOH DILUTION TANK
FLOW CONTROL TOTALIZER TYPICAL (4 PLACES)
DRY MATERIAL DISPENSER
LC
NaOH DILUTION TANK
SAMPLE BOX (3 PLACES)
LiOH DILUTION TANK
FLOW CONTROL/ TOTALIZER TYPICAL (3 PLACES)
COOLANT SUPPLY AND RETURN (TYPICAL 3 PLACES)
TC
WEIGHT SENSOR/ TOTALIZER INCLUDED
FILTER TYPICAL (3 PLACES)
REDUNDANT PUMPS
ORDER OF ADDITIONAL VALVE TYPICAL (3 PLACES)
CONTINUOUS CAUSTIC SOLUTION MIXING MODULE

(FIGURE 2)


DRY MATERIAL
DISPENSERS TYP. 3 PLC.'S
WEIGHT SENSOR/
TOTALIZER
INCLUDED
POTABLE
WATER
D.I. SYSTEM WITH
FILTRATION UNITS
MOH
CHILLER
SYSTEM
LEVEL
CONTROL
TYPICAL
4 PLACES
KOH
DILUTION
TANK
NaOH
DILUTION
TANK
LiOH
DILUTION
TANK
WATER FLOW CONTROL/
TOTALIZER
TYPICAL (4 PLACES)
REDUNDANT
PUMPS
BATCH
ALKALI
MIXING
MODULE
SAMPLE
VALVE
TYPICAL (4 PLACES)
TO
USER
LIOH IN-LINE
HEAT EXCHANGER
FLOW CONTROL/
TOTALIZER
TYPICAL (4 PLACES)
FILTER
LIOH IN-LINE
MIXER PUMP
MIXED
ALKALI
STORAGE
TANK
INSULATION

(FIGURE 3)


DRY MATERIAL DISPENSERS TYP. 3 PLC.'S
POTABLE WATER
D.I. SYSTEM WITH FILTRATION UNITS
MOH CHILLER SYSTEM
WEIGHT SENSOR/ TOTALIZER INCLUDED
GRAVITY FEED
LEVEL CONTROL TYPICAL 4 PLACES
KOH DILUTION TANK
GRAVITY FEED
KOH TRANSFER PUMP
NaOH DILUTION TANK
LiOH DILUTION TANK
WATER FLOW CONTROL/ TOTALIZER TYPICAL (4 PLACES)
NaOH TRANSFER PUMP
BATCH ALKALI MIXING MODULE
SAMPLE VALVE TYPICAL (4 PLACES)
TO USER
LIOH IN-LINE HEAT EXCHANGER
FLOW CONTROL/ TOTALIZER TYPICAL (4 PLACES)
LIOH IN-LINE MIXER PUMP
LiOH TRANSFER PUMP
FILTER
MIXED ALKALI STORAGE TANK
INSULATION

(FIGURE 4)

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SECTION

2

SPECIFICATION CLASS "K"

Service: Peroxide, Caustics and D.I. Water

Service Limits: 150 PSIG @ 250°F

ITEM	SIZE	DESCRIPTION	
PIPE	½" – 2"	Sch. 40S, Stainless Steel, ASTM A312, TP 316L, seamless, PE	
	3" – 6"	Sch. 10S, Stainless Steel, ASTM A312, TP 316L, Seamless BE	
FITTINGS	½" – 2"	3000# forged Stainless Steel, socket weld, ASTM A182, Gr. F316L	
	3" –6"	Sch. 10S, Stainless Steel, ASTM A403, Gr. WP316L, Butt Weld	
BRANCH CONNECTIONS	RUN	BRANCH	USE
	½" – 2"	Full or Reducing	Tee
	3" – 6"	2" – Smaller	Sockolet
	3" – 6"	Full or Reducing (Min 3")	Tee or Weldolet
FLANGES	½" – 2"	150# RF, Stainless Steel, ASTM A182, Gr. F316L, socket weld, Sch. 40S bore	
	3" –6"	150# RF, 316L Stainless Steel, ASTM A105, Slip-on	
BOLTING	All Sizes	Mach bolts w/hex nuts to ASTM A307, Gr. B..	
GASKETS	All Sizes	150#, 1/8" thick, Reinforced Teflon. Use ring style gaskets against RF flanges, full face gaskets otherwise.	

Po	3-24-04	Issue for Final Report			
Rev. No.	Date	Description	Rev. No.	Date	Description

VALVE	SIZE	DESCRIPTION	TAG NO.
BALL	½" – 2"	316 Stainless Steel Body and Ball, SW ends, 3 Piece Style, Teflon Seats and Stem Packing (Apollo 85-200 Series or Equal)	
	3" – 6"	316 Stainless Steel Body and Ball, 150# RF Flanged Ends, Teflon Seats and Seals (Apollo 87A-100 Series or Equal) 6" to be Gear Operated	
CHECK	½" – 2"	316 Stainless Steel Body and Disc, Swing Type, SW Ends (Powell 2341 SWE or Equal)	
	3" – 6"	**HYDROGEN PEROXIDE ONLY** 316 Stainless Steel Body and Disc, Viton Seats, Wafer Type (Duo-Check G15 CMP or Equal)	
	3" – 6"	**SODIUM HYDROXIDE, POTASSIUM HYDROXIDE AND LITHIUM HYDROXIDE** 316 Stainless Steel Body and Disc, EPDM Seats Wafer Type (Duo-Check G15 CMP or Equal)	

Po	3-24-04	Issue for Final Report			
Rev. No.	Date	Description	Rev. No.	Date	Description

SPECIFICATION CLASS "A"

Service: Plant Air, Cooling Water

Service Limits: 150°F @ 150 PSIG

ITEM	SIZE	DESCRIPTION	
PIPE	½" – 1 ½" 2" – 8"	ERW, C.S., ASTM A120, Galv., Sch. 80, T&C ERW or smls., C.S. ASTM A53, Gr. B, Sch 40, BE	
FITTINGS	½" – 1 ½" 2" – 8"	300# MI, Galv., Scrd., ASTM A47 to ANSI B16.3 C.S., BW Ends, Sch 40, ASTM A234, Gr. WPB to ANSI B16.9	
UNIONS	½" – 1 ½"	300# MI, Galv., Scrd., ASTM A47, Bronze-to-Iron Joint	
PLUGS	½" – 1 ½"	Round Solid Steel, Scrd. To ANSI B16.11	
BRANCH CONNECTIONS	RUN	BRANCH	USE
	½" – 1 ½"	Full or Reducing	MI Tee
	2" - 8"	1 ½" or Smaller	Threadolet
	2" – 8"	Full or Reducing (2" min.)	Reducing Tee or Weldolet
FLANGES	½" – 1 ½" 2" – 8"	150# FF, C.S., Scrd., ASTM A105 to ANSI B16.5 150# FF, C.S., Slip-on, ASTM A105 to ANSI B16.5	
BOLTING	All	Mach. Bolts, w/Hex Nuts to ASTM A-307, Gr. B	
GASKETS		125#, 1/8" Thick, Full Face or Ring Type, Neoprene.	

VALVES (See Note 1)	SIZE	DESCRIPTION	TAG NO.
GATE	2" – 8"	125#, Cast Iron Body, Bronze Trim, OS &Y. (Powell 1793 or Equal)	
GLOBE	½" – 1 ½"	Iron Body, Chrome Trim (Crane 244XR or Equal)	
CHECK	½" – 1 ½" 2" – 8"	Bronze, Swing Type 125#, CI, Wafer, Lift Type (Duo-Chek G12 HMP or Equal)	
BUTTERFLY	2" – 8"	150#, CI, Wafer, Buna N Seat, DI Disc (Apollo 140 CFN or Equal)	
BALL	¼" – 1 ½"	Bronze Body, 316 Stainless Steel Ball and Stem, Screwed Ends, PTFE Seats and Stem Seal (Apollo 70-100 Series or Equal)	

NOTES: 1. For further valve information, see the individual valve specification.

Po	3-24-04	Issue for Final Report			
Rev. No.	Date	Description	Rev. No.	Date	Description

SECTION

3

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-001

SERVICE: Lithium Hydroxide Tank Water Additions

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FQIC-0100	Flow Totalize Controller	PLC	Pulse				
FT-0100	Mass Flow Meter	FLD	AI				
FV-0100	Shut Off Valve	FLD					
FY-0100	Solenoid	PLC	DO				
RO-0100	Orifice Plate	FLD					
ZI-0100	Position Indication	PLC					
ZSC-0100	Pos. Switch Closed	FLD	DI				
ZSO-0100	Pos. Switch Open	FLD	DI				

SERVICE: Lithium Hydroxide Inline Mixing Pump

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FAL-0101	Flow Alarm Low	PLC					
FSL-0101	Flow Switch Low	FLD	DI				
YA-0101	Motor Fault	PLC					
YI-0101	Status Indication	PLC					
YS-0101	Run Contact	FLD	DI				
YY-0101	Starter Coil	FLD	DO				

SERVICE: Lithium Hydroxide Powder Additions Bag Manipulators

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
HY-0102-A	Solenoid Valve	FURN'D	DO				
HY-0102-B	Solenoid Valve	FURN'D	DO				
HY-0102-C	Solenoid Valve	FURN'D	DO				
HY-0102-D	Solenoid Valve	FURN'D	DO				

SERVICE: Lithium Hydroxide Dilution Tank Powder Addition Air

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
PRV-0103	Pressure Regulator	FURN'D					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Lithium Hydroxide Dilution Tank Powder Addition							
FV-0105	Rotary Feed Valve	FURN'D					
HS-0105	Hand Switch	FURN'D					
HY-0105-A	Feed Gate	FURN'D	DO				
HY-0105-B	Feed Gate	FURN'D	DO				
SC-0105	Speed Controller	FURN'D					
SIC-0105	Speed Ind. Controller	PLC	A0				
WE-0105	Load Cell	FURN'D					
WIT-0105	Weight Ind. Transmitter	FLD	AI				
WQI-0105	Weight Totalizer	FLD					
WQIC-0105	Weight Ind. Controller	PLC					
SERVICE: Lithium Hydroxide Dilution Tank Level							
LI-0106	Level Indicator	PLC					
LT-0106	Level Transmitter	FLD	AI				
SERVICE: Lithium Hydroxide Dilution Tank Agitator							
YA-0107	Motor Fault	PLC					
YI-0107	Status Indication	PLC					
YS-0107	Run Contact	FLD	DI				
YY-0107	Starter Coil	FLD	DO				
SERVICE: Lithium Hydroxide Dilution Tank Pressure Conservation Valve							
PCV-0108	Conservation Vent	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Lithium Hydroxide Dilution Tank Temperature Control							
TCV-0109-A	Temperature Control Valve	FLD					
TCV-0109-B	Temperature Control Valve	FLD					
TE-0109	RTD	FLD					
TIC-0109-A	PID Loop	PLC					
TIC-0109-B	PID Loop	PLC					
TT-0109	Temperature Transmitter	FLD	AI				
TY-0109-A	I/P	FLD	A0				
TY-0109-B	I/P	FLD	A0				
SERVICE: Lithium Hydroxide Transfer Pump							
PAH-0110	Pressure Alarm High	PLC					
PAL-0110	Pressure Alarm Low	PLC					
PSH-0110	Pressure Switch High	FLD	DI				
PSL-0110	Pressure Switch Low	FLD	DI				
YA-0110	Motor Fault	PLC					
YI-0110	Status Indication	PLC					
YS-0110	Run Contact	FLD	DI				
YY-0110	Starter Coil	FLD	DO				
SERVICE: Lithium Hydroxide Dilution Tank Recirculation Valve							
CV-0112	Shut Off Valve	FLD					
CY-0112	Solenoid Valve	PLC	DO				
ZI-0112	Position Indication	PLC					
ZSC-0112	Pos. Switch Closed	FLD	DI				
ZSO-0112	Pos. Switch Open	FLD	DI				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Lithium Hydroxide Dilution Tank to MOH Make Up Tank							
CV-0114	Shut Off Valve	FLD					
CY-0114	Solenoid Valve	PLC	DO				
DI-0114	Density Indicator	PLC	AI				
FQIC-0114	Flow Totalize Controller	PLC	Pulse				
FT-0114	Mass Flow Meter	FLD	AI				
ZI-0114	Position Indication	PLC					
ZSC-0114	Pos. Switch Closed	FLD	DI				
ZSO-0114	Pos. Switch Open	FLD	DI				
SERVICE: Lithium Hydroxide Transfer Pump Filter Differential Pressure							
PDI-0117	Diff. Pressure Ind.	FLD					
SERVICE: Lithium Hydroxide Dilution Tank Temperature							
TI-0120	Temperature Gauge	FLD					
SERVICE: Lithium Hydroxide Dilution Tank Chiller Line Temperature							
TI-0121	Temperature Gauge	FLD					
SERVICE: Lithium Hydroxide Dilution Tank Chiller Jacket Flow							
FI-0122	Rotameter	FLD					
SERVICE: Lithium Hydroxide Dilution Tank Chiller Coil Flow							
FI-0123	Rotameter	FLD					
SERVICE: Lithium Hydroxide Solution Heat Exchanger							
TCV-0124	Temperature Control Valve	FLD					
TE-0124	RTD	FLD					
TIC-0124	Temp. Ind. Controller	PLC					
TT-0124	Temperature Transmitter	FLD	AI				
TY-0124	I/P	FLD	A0				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Lithium Hydroxide Solution Mixer Bypass							
CV-0125-A	Shut Off Valve	FLD	DO				
CV-0125-B	Shut Off Valve	FLD	DO				
CV-0125-C	Shut Off Valve	FLD	DO				
CY-0125-A	Solenoid Valve	FLD	DO				
CY-0125-B	Solenoid Valve	FLD	DO				
CY-0125-C	Solenoid Valve	FLD	DO				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-002

SERVICE: Sodium Hydroxide Tank Water Additions

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FQIC-0200	Flow Totalize Controller	PLC	Pulse				
FT-0200	Mass Flow Meter	FLD	AI				
FV-0200	Shut Off Valve	FLD					
FY-0200	Solenoid	PLC	DO				
RO-0200	Orifice Plate	FLD					
ZI-0200	Position Indication	PLC					
ZSC-0200	Pos. Switch Closed	FLD	DI				
ZSO-0200	Pos. Switch Open	FLD	DI				

SERVICE: Sodium Hydroxide Powder Additions Bag Manipulators

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
HY-0202-A	Solenoid Valve	FURN'D	DO				
HY-0202-B	Solenoid Valve	FURN'D	DO				
HY-0202-C	Solenoid Valve	FURN'D	DO				
HY-0202-D	Solenoid Valve	FURN'D	DO				

SERVICE: Sodium Hydroxide Dilution Tank Powder Addition Air

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
PRV-0203	Pressure Regulator	FURN'D					

SERVICE: Sodium Hydroxide Dilution Tank Powder Addition

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FV-0205	Rotary Feed Valve	FURN'D					
HS-0205	Hand Switch	FURN'D					
HY-0205-A	Feed Gate	FURN'D	DO				
HY-0205-B	Feed Gate	FURN'D	DO				
SC-0205	Speed Controller	FURN'D					
SIC-0205	Speed Ind. Controller	PLC	A0				
WE-0205	Load Cell	FURN'D					
WIT-0205	Weight Ind. Transmitter	FLD	AI				
WQI-0205	Weight Totalizer	FLD					
WQIC-0205	Weight Ind. Controller	PLC					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Sodium Hydroxide Dilution Tank Level							
LI-0206	Level Indicator	PLC					
LT-0206	Level Transmitter	FLD	AI				
SERVICE: Sodium Hydroxide Dilution Tank Agitator							
YA-0207	Motor Fault	PLC					
YI-0207	Status Indication	PLC					
YS-0207	Run Contact	FLD	DI				
YY-0207	Starter Coil	FLD	DO				
SERVICE: Sodium Hydroxide Dilution Tank Pressure Conservation Valve							
PCV-0208	Conservation Vent	FLD					
SERVICE: Sodium Hydroxide Dilution Tank Temperature Control							
TCV-0209-A	Temperature Control Valve	FLD					
TCV-0209-B	Temperature Control Valve	FLD					
TE-0209	RTD	FLD					
TIC-0209-A	PID Loop	PLC					
TIC-0209-B	PID Loop	PLC					
TT-0209	Temperature Transmitter	FLD	AI				
TY-0209-A	I/P	FLD	A0				
TY-0209-B	I/P	FLD	A0				
SERVICE: Sodium Hydroxide Transfer Pump							
PAH-0210	Pressure Alarm High	PLC					
PAL-0210	Pressure Alarm Low	PLC					
PSH-0210	Pressure Switch High	FLD	DI				
PSL-0210	Pressure Switch Low	FLD	DI				
YA-0210	Motor Fault	PLC					
YI-0210	Status Indication	PLC					
YS-0210	Run Contact	FLD	DI				
YY-0210	Starter Coil	FLD	DO				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Sodium Hydroxide Dilution Tank Recirculation Valve							
CV-0212	Shut Off Valve	FLD					
CY-0212	Solenoid Valve	PLC	DO				
ZI-0212	Position Indication	PLC					
ZSC-0212	Pos. Switch Closed	FLD	DI				
ZSO-0212	Pos. Switch Open	FLD	DI				
SERVICE: Sodium Hydroxide Dilution Tank to MOH Make Up Tank							
CV-0214	Shut Off Valve	FLD					
CY-0214	Solenoid Valve	PLC	DO				
DI-0214	Density Indicator	PLC	AI				
FQIC-0214	Flow Totalize Controller	PLC	Pulse				
FT-0214	Mass Flow Meter	FLD	AI				
ZI-0214	Position Indication	PLC					
ZSC-0214	Pos. Switch Closed	FLD	DI				
ZSO-0214	Pos. Switch Open	FLD	DI				
SERVICE: Sodium Hydroxide Transfer Pump Filter Differential Pressure							
PDI-0217	Diff. Pressure Ind.	FLD					
SERVICE: Sodium Hydroxide Dilution Tank Temperature							
TI-0220	Temperature Gauge	FLD					
SERVICE: Sodium Hydroxide Dilution Tank Chiller Line Temperature							
TI-0221	Temperature Gauge	FLD					
SERVICE: Sodium Hydroxide Dilution Tank Chiller Jacket Flow							
FI-0222	Rotameter	FLD					
SERVICE: Sodium Hydroxide Dilution Tank Chiller Coil Flow							
FI-0223	Rotameter	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-003

SERVICE: Potassium Hydroxide Tank Water Additions

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FQIC-0300	Flow Totalize Controller	PLC	Pulse				
FT-0300	Mass Flow Meter	FLD	AI				
FV-0300	Shut Off Valve	FLD					
FY-0300	Solenoid	PLC	DO				
RO-0300	Orifice Plate	FLD					
ZI-0300	Position Indication	PLC					
ZSC-0300	Pos. Switch Closed	FLD	DI				
ZSO-0300	Pos. Switch Open	FLD	DI				

SERVICE: Sodium Hydroxide Powder Additions Bag Manipulators

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
HY-0302-A	Solenoid Valve	FURN'D	DO				
HY-0302-B	Solenoid Valve	FURN'D	DO				
HY-0302-C	Solenoid Valve	FURN'D	DO				
HY-0302-D	Solenoid Valve	FURN'D	DO				

SERVICE: Potassium Hydroxide Dilution Tank Powder Addition Air

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
PRV-0303	Pressure Regulator	FURN'D					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Potassium Hydroxide Dilution Tank Powder Addition							
FV-0305	Rotary Feed Valve	FURN'D					
HS-0305	Hand Switch	FURN'D					
HY-0305-A	Feed Gate	FURN'D	DO				
HY-0305-B	Feed Gate	FURN'D	DO				
SC-0305	Speed Controller	FURN'D					
SIC-0305	Speed Ind. Controller	PLC	A0				
WE-0305	Load Cell	FLD					
WE-0305	Load Cell	FURN'D					
WIT-0305	Weight Ind. Transmitter	FLD	AI				
WQI-0305	Weight Totalizer	FLD					
WQIC-0305	Weight Ind. Controller	PLC					
SERVICE: Potassium Hydroxide Dilution Tank Level							
LI-0306	Level Indicator	PLC					
LT-0306	Level Ind. Transmitter	FLD	AI				
SERVICE: Potassium Hydroxide Dilution Tank Agitator							
YA-0307	Motor Fault	PLC					
YI-0307	Status Indication	PLC					
YS-0307	Run Contact	FLD	DI				
YY-0307	Starter Coil	FLD	DO				
SERVICE: Potassium Hydroxide Dilution Tank Pressure Conservation Valve							
PCV-0308	Conservation Vent	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Potassium Hydroxide Dilution Tank Temperature Control							
TCV-0309-A	Temperature Control Valve	FLD					
TCV-0309-B	Temperature Control Valve	FLD					
TE-0309	RTD	FLD					
TIC-0309-A	PID Loop	PLC					
TIC-0309-B	PID Loop	PLC					
TT-0309	Temperature Transmitter	FLD	AI				
TY-0309-A	I/P	FLD	A0				
TY-0309-B	I/P	FLD	A0				
SERVICE: Potassium Hydroxide Transfer Pump							
PAH-0310	Pressure Alarm High	PLC					
PAL-0310	Pressure Alarm Low	PLC					
PSH-0310	Pressure Switch High	FLD	DI				
PSL-0310	Pressure Switch Low	FLD	DI				
YA-0310	Motor Fault	PLC					
YI-0310	Status Indication	PLC					
YS-0310	Run Contact	FLD	DI				
YY-0310	Starter Coil	FLD	DO				
SERVICE: Potassium Hydroxide Dilution Tank Recirculation Valve							
CV-0312	Shut Off Valve	FLD					
CY-0312	Solenoid Valve	PLC	DO				
ZI-0312	Position Indication	PLC					
ZSC-0312	Pos. Switch Closed	FLD	DI				
ZSO-0312	Pos. Switch Open	FLD	DI				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Potassium Hydroxide Dilution Tank to MOH Make Up Tank							
CV-0314	Shut Off Valve	FLD					
CY-0314	Solenoid Valve	PLC	DO				
DI-0314	Density Indicator	PLC	AI				
FQIC-0314	Flow Totalize Controller	PLC	Pulse				
FT-0314	Mass Flow Meter	FLD	AI				
ZI-0314	Position Indication	PLC					
ZSC-0314	Pos. Switch Closed	FLD	DI				
ZSO-0314	Pos. Switch Open	FLD	DI				
SERVICE: Potassium Hydroxide Transfer Pump Filter Differential Pressure							
PDI-0317	Diff. Pressure Ind.	FLD					
SERVICE: Potassium Hydroxide Dilution Tank Temperature							
TI-0320	Temperature Gauge	FLD					
SERVICE: Potassium Hydroxide Dilution Tank Chiller Line Temperature							
TI-0321	Temperature Gauge	FLD					
SERVICE: Potassium Hydroxide Dilution Tank Chiller Jacket Flow							
FI-0322	Rotameter	FLD					
SERVICE: Potassium Hydroxide Dilution Tank Chiller Coil Flow							
FI-0323	Rotameter	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-004

SERVICE: MOH Make Up Tank Water Additions

FQIC-0400	Flow Totalize Controller	PLC	Pulse				
FT-0400	Mass Flow Meter	FLD	AI				
FV-0400	Shut Off Valve	FLD					
FY-0400	Solenoid	PLC	DO				
RO-0400	Orifice Plate	FLD					
ZI-0400	Position Indication	PLC					
ZSC-0400	Pos. Switch Closed	FLD	DI				
ZSO-0400	Pos. Switch Open	FLD	DI				

SERVICE: MOH Make Up Tank Pressure Breather Valve

PSE-0402	Pressure Breather Valve	FLD					

SERVICE: MOH Make Up Tank Pressure Relief Valve

PSV-0403	Pressure Relief Valve	FLD					

SERVICE: MOH Make Up Tank Level

LI-0406	Level Indicator	PLC					
LT-0406	Level Ind. Transmitter	FLD	AI				

SERVICE: MOH Make Up Tank Agitator

YA-0407	Motor Fault	PLC					
YI-0407	Status Indication	PLC					
YS-0407	Run Contact	FLD	DI				
YY-0407	Starter Coil	FLD	DO				

SERVICE: MOH Make Up Tank Pressure Conservation Valve

PCV-0408	Conservation Vent	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: MOH Make Up Tank Temperature Control							
TCV-0409-A	Temperature Control Valve	FLD					
TCV-0409-B	Temperature Control Valve	FLD					
TE-0409	RTD	FLD					
TIC-0409-A	PID Loop	PLC					
TIC-0409-B	PID Loop	PLC					
TT-0409	Temperature Transmitter	FLD	AI				
TY-0409-A	I/P	FLD	A0				
TY-0409-B	I/P	FLD	A0				
SERVICE: MOH Make Up Tank Transfer Pump							
FAL-0410	Flow Alarm Low	PLC					
FSL-0410	Flow Switch Low	FLD	DI				
YA-0410	Motor Fault	PLC					
YI-0410	Status Indication	PLC					
YS-0410	Run Contact	FLD	DI				
YY-0410	Starter Coil	FLD	DO				
SERVICE: MOH Make Up Tank Recirculation Valve							
CV-0412	Shut Off Valve	FLD					
CY-0412	Solenoid Valve	PLC	DO				
RO-0412	Orifice Plate	FLD					
ZI-0412	Position Indication	PLC					
ZSC-0412	Pos. Switch Closed	FLD	DI				
ZSO-0412	Pos. Switch Open	FLD	DI				

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: MOH Make Up Tank to Neutralization Tank							
CV-0414	Shut Off Valve	FLD					
CY-0414	Solenoid Valve	PLC	DO				
DI-0414	Density Indicator	PLC	AI				
FQIC-0414	Flow Totalize Controller	PLC	Pulse				
FT-0414	Mass Flow Meter	FLD	AI				
RO-0414	Orifice Plate	FLD					
ZI-0414	Position Indication	PLC					
ZSC-0414	Pos. Switch Closed	FLD	DI				
ZSO-0414	Pos. Switch Open	FLD	DI				
SERVICE: MOH Make Up Tank Temperature							
TI-0420	Temperature Gauge	FLD					
SERVICE: MOH Make Up Tank Chiller Line Temperature							
TI-0421	Temperature Gauge	FLD					
SERVICE: MOH Make Up Tank Chiller Jacket Flow							
FI-0422	Rotameter	FLD					
SERVICE: MOH Make Up Tank Chiller Coil Flow							
FI-0423	Rotameter	FLD					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-005

SERVICE: Deionized Water Transfer Pump

YA-0501	Motor Fault	PLC	
YI-0501	Status Indication	PLC	
YS-0501	Run Contact	FLD	DI
YY-0501	Starter Coil	FLD	DO

SERVICE: Deionized Water Wash Pump

YA-0502	Motor Fault	PLC	
YI-0502	Status Indication	PLC	
YS-0502	Run Contact	FLD	DI
YY-0502	Starter Coil	FLD	DO

SERVICE: Deionized Water Transfer Pump Discharge Pressure

PI-0503	Pressure Gauge	FLD	

SERVICE: Deionized Water Wash Pump Discharge Pressure

PI-0504	Pressure Gauge	FLD	

SERVICE: Deionized Water Transfer Pump Recirculation Pressure

PCV-0505	Pressure Regulator	FLD	
PI-0505-A	Pressure Gauge	FLD	
PI-0505-B	Pressure Gauge	FLD	

SERVICE: Deionized Water Storage Tank Level

LIC-0506	Level Ind. Control	PLC	
LIT-0506	Level Ind. Transmitter	FLD	AI
LV-0506	Shut Off Valve	FLD	
LY-0506	Solenoid Valve	FLD	DO

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
SERVICE: Deionized Water System							
AAH-0507	Conductivity High Alarm	FURN'D					
AE-0507	Conductivity Sensor	FURN'D					
PI-0507-A	Pressure Gauge	FURN'D					
PI-0507-B	Pressure Gauge	FURN'D					
PI-0507-C	Pressure Gauge	FURN'D					

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS

PID NO: 3160-F-006

SERVICE: MHP Chiller Feed Pumps

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
FAL-0601	Flow Alarm Low	PLC					
FSL-0601	Flow Switch Low	FLD	DI				
TAL-0601	Temperature Alarm Low	PLC					
TSL-0601	Temperature Switch Low	FURN'D	DI				
YA-0601	Motor Fault	PLC					
YI-0601	Status Indication	PLC					
YS-0601	Run Contact	FLD	DI				
YY-0601	Starter Coil	FLD	DO				

SERVICE: Chiller Expansion Tank Level

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
LG-0602	Sight Glass	FLD					

SERVICE: MHP Chiller Recirculation Pressure

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
PCV-0604	Pressure Regulator	FLD					
PI-0604-A	Pressure Gauge	FLD					
PI-0604-B	Pressure Gauge	FLD					

Instrument Summary

TAG NO.	TYPE	LOC	I/O TYPE	MANUFACTURER	MODEL NO.	VENDOR	COMMENTS
PID NO: 3160-F-007							
SERVICE: Air Compressor							
PDI-0700	Diff. Pressure Ind.	FURN'D					
PSV-0700	Pressure Relief Valve	FURN'D					
SERVICE: High Efficiency Coalescing Filter							
PDI-0701	Diff. Pressure Ind.	FURN'D					
SERVICE: General Purpose Filter							
PDI-0702	Diff. Pressure Ind.	FURN'D					

SECTION

4

EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018
AGITATORS

REV: P2
DATE: 3/26/04

Number	Name	Service	Agitation Level & Description	Torque (lb ft)	Working Tank Volume (gal)	Density (lb/cu ft) / Viscosity (cp)	Torque / Volume (ft lb/gal)	Min. / Max. Temperature (F)	Material of Construction	Speed (rpm)	Power (HP)	Motor Frame	Volts/Phase/Freq.	Seal Type	Impeller Flow: Direct / Circulation (gpm)	QTY / Impeller Dia. (in)	Shaft Length / dia (in)	Connection Type	Impeller Type	Gearbox	QTY.
A-202	MOH Make-Up Tank Agitator	22.6% Alkali Mix	Tank mixer for making MOH or MHP in Tank T-200; Miscible liquids < 1000 ft-lbs/gal	68.5	1100	75 / 13.4	0.06	32 to 5	Wetted: 316 SS Passivated; Shaft Pkg & Gaskets Teflon	117	1.5	140TC	230-460/3/60	Packed Seal stuffing box with PTFE packing material	4674 / 9348 to 6500 / 13000	1 / 27.4	78" / 2"	6" 150 lb RF Flng.	Chemineer SC3	Cast-iron housing-right angle assembly	1
A-302	Lithium Hydroxide Dilution Tank Agitator	10.4% LiOH Soln.	LiOH dissolution of solids into liquid	34	573	74 / 3.2	0.06	amb to 212	Wetted: 316 SS; Shaft Pkg & Gaskets Teflon	117	1	140TC	230-460/3/60	Packed Seal stuffing box with PTFE packing material	4661 / 9322 to 3850 / 7700	1 / 25"	63" / 1.5"	6" 150 lb RF Flng	Chemineer SC3	Cast-iron housing-right angle assembly	1
A-402	Sodium Hydroxide Dilution Tank Agitator	30% NaOH Soln.	NaOH dissolution of solids into liquid	34	595	83 / 12	0.06	amb to 212	Wetted: 316 SS; Shaft Pkg & Gaskets Teflon	117	1	140TC	230-460/3/60	Packed Seal stuffing box with PTFE packing material	3241 / 6482 to 3850 / 7700	1 / 25"	63" / 1.5"	6" 150 lb RF Flng.	Chemineer SC3	Cast iron housing-right angle assembly	1
A-502	Potassium Hydroxide Dilution Tank Agitator	45% KOH Soln.	KOH dissolution of solids into liquid	34	340	90 / 3.8	0.1	amb to 212	Wetted: 316 SS; Shaft Pkg & Gaskets Teflon	117	1	140C	230-460/3/60	Packed Seal stuffing box with PTFE packing material	3241 / 6482 to 3850 / 7700	1 / 25"	63" / 1.5"	6" 150 lb RF Flng	Chemineer SC3	Cast iron housing-right angle assembly	1

amb.	Ambient Conditions
Flng.	Flanged
N/A	not applicable
pkg.	Packing
soln.	Solution
SS	Stainless Steel
RF	Raised Face (flange)

EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018

REV: P2
DATE: 3/26/04

FILTERS & STRAINERS

Number	Name	Service	Filter or Strainer Description	Flow Rate (gpm)	Solids & Size	Density (lb/cu ft) / Viscosity (cp)	Min. / Max. Temp. (F)	Housing Material of Construction	Filter Material of Construction	Filter pore size or rating	Pressure Drop @ Rated Flow (psi)	Electrical Requirements If Applicable	Unit Dimensions	Design Pressure (psig)	Design Temp. (F)	Connections	Connection Type	QTY.	Model
SP-21	Lithium Hydroxide Transfer Pump Strainer	10.4% LiOH Soln.	Strainer to remove large impurities from transfer lines	75	Remove solids 1/2" or greater	74 / 3.2	amb - 212	316 SS / TFE Seals	316 SS basket	½"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-21	Sodium Hydroxide Transfer Pump Strainer	30% NaOH Soln.	Strainer to remove large impurities from transfer lines	75	Remove solids 1/2" or greater	83 / 12	amb. - 212	316 SS / TFE Seals	316 SS basket	½"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-21	Potassium Hydroxide Transfer Pump Strainer	45% KOH Soln.	Strainer to remove large impurities from transfer lines	75	Remove solids 1/2" or greater	90 / 3.8	amb. - 212	316 SS / TFE Seals	316 SS basket	½"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-2	MOH Transfer Pump Strainer	22.6% Alkali Mix	Strainer to remove large impurities from transfer lines	100	Remove solids 1/32" or greater	75 / 13.4	32 - 5	316 SS / TFE Seals	316 SS basket	1/32"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-2	Deionized Water Pump Strainer A	100% DI Water	Strainer to remove large impurities from transfer lines	75	Remove solids 1/32" or greater	62.31 / .95	amb.	316 SS / TFE Seals	316 SS basket	1/32"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-2	Deionized Wash Water Pump Strainer A	100% DI Water	Strainer to remove large impurities from transfer lines	75 -100	Remove solids 1/32" or greater	62.31 / .95	amb.	316 SS / TFE Seals	316 SS basket	1/32"	0.175 psi for clean water	N/A	Housing OD = 6.5" F/F Length = 13.125" Height = 18.75"	200	300	3"	150 lb RF Flng.	1	Hayward 72
SP-18	Chiller Pump Strainer	Syltherm 800	Strainer to remove large impurities from transfer lines	390	Remove solids 1/4" or greater	60 / 19-22	-13 to 4	316 SS with Ductile Iron exterior trim w/ TFE Seals	316 SS basket	1/32"	0.25 psi for clean water	N/A	Housing OD = 10" F/F Length = 19.625" Height = 28.125"	200	300	6"	150 lb RF Flng.	1	Hayward 72

CASE ENGINEERING, INC.
5925 Imperial Parkway, Suite 226 • Mulberry, FL 33860

EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018

REV: P2
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FILTERS & STRAINERS

Number	Name	Service	Filter or Strainer Description	Flow Rate (gpm)	Solids & Size	Density (lb/cu ft) / Viscosity (cp)	Min. / Max. Temp. (F)	Housing Material of Construction	Filter Material of Construction	Filter pore size or rating	Pressure Drop @ Rated Flow (psi)	Electrical Requirements If Applicable	Unit Dimensions	Design Pressure (psig)	Design Temp. (F)	Connections	Connection Type	QTY.	Model
F-303	Lithium Hydroxide Transfer Filter	10.4% LiOH Soln	Filter sized to remove micron sized impurities	75	1-10 microns	74 / 3.2	amb.-120	316L SS with stainless leg assembly and Teflon enveloped gasket	Bag filter Polypropylene Seamless	3 micron absolute	5.5 clean; 10-15 dirty	N/A	Housing OD = approx. 10" F/F Length = 11.75" Height = 47.625"	150	200 max.	2" IN-LINE	150 lb RF Flng.	1	FSI FSPN85-1-316L-150-2"FLG
F-403	Sodium Hydroxide Transfer Filter	30% NaOH Soln.	Filter sized to remove micron sized impurities	75	1-10 microns	83 / 12	amb.-120	316L SS with stainless leg assembly and Teflon enveloped gasket	Bag filter Polypropylene Seamless	3 micron absolute	5.5 clean; 10-15 dirty	N/A	Housing OD = approx. 10" F/F Length = 11.75" Height = 47.625"	150	200 max.	2" IN-LINE	150 lb RF Flng.	1	FSI FSPN85-1-316L-150-2"FLG
F-503	Potassium Hydroxide Transfer Filter	45% KOH Soln.	Filter sized to remove micron sized impurities	75	1-10 microns	90 / 3.8	amb.-120	316L SS with stainless leg assembly and Teflon enveloped gasket	Bag filter Polypropylene Seamless	3 micron absolute	5.5 clean; 10-15 dirty	N/A	Housing OD = approx. 10" F/F Length = 11.75" Height = 47.625"	150	200 max.	2" IN-LINE	150 lb RF Flng.	1	FSI FSPN85-1-316L-150-2"FLG
F-1002 A	High Efficiency Coalescing Filter	Air with humidity and oil	123 scfm capacity high efficiency Coalescing Filter	102cfm @ 125 psig	N/A	0.073 / 0.0175	amb. - 123	Std. MOC per compressor package manufacturer	Std. MOC per compressor package manufacturer			N/A	5.1" W x 13.8" H	150	240	3/4"	NPT	1	Ingersoll-Rand IRHE123
F-1003A/B	Heatless Desiccant Air Dryers	Humid air	Desiccant Dryer	102cfm @ 125 psig	N/A	0.073 / 0.0175	amb. - 123	Std. MOC per compressor package manufacturer	Std. MOC per compressor package manufacturer			N/A	21.7" L x 7.9" W x 55.7" H	150	240	3/4"	NPT	2	Ingersoll-Rand TZM106
F-1004A	General Purpose Filter	Dry air	123 scfm capacity general purpose filter	102cfm @ 125 psig	N/A	0.073 / 0.0175	amb. - 123	Std. MOC per compressor package manufacturer	Std. MOC per compressor package manufacturer			N/A	5.1" W x 13.8" H	150	240	3/4"	NPT	1	Ingersoll-Rand IRGP123

amb.	Ambient Conditions
cfm	cubic feet per minute
F/F	Face of flange to face of flange
Flng.	Flanged
N/A	not applicable
OD	Outside diameter
psi	pounds per square inch
psig	pounds per square inch (gauge)
RF	Raised Face (flange)
scfm	standard cubic feet per minute (14.7 psia, 32 F)
soln.	Solution
SS	Stainless Steel
w/	with

EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018

REV: P2
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HEAT EXCHANGERS & COOLERS

Number	Name	Process Side / Utility or Coolant Side	Overall X-fer Coefficient (BTU/sq ft hr F)	Duty basis (BTU/hr)	Process Volume (gal)	Process Flow (gpm)	Process Density (lb/cu ft) / Viscosity (cp)	Process Temp. (F)	Utility Fluid Density (lb/cu ft) / Viscosity (cp)	Utility Temp. Inlet (F)	Utility Temp. Outlet (F)	Specific Heat Process / Utility (BTU/lb F)	Area Required (sq ft)	Material of Construction	Type	Power (HP)	Volts/Phase/Freq.	Mounting Description	Actual Area (sq ft)	Conn. Process / Utility	Conn. Type	Coil Dia. (inch) / Length (ft)	L x W x H (inches)	QTY.
H-204	MOH Heat Exchanger Coil & Jacket	22.6% Alkali Mix / Syltherm 800	65 coil / 25 jacket	240927 coil / 240927 Jacket	1100	Mixed Tank Entrained Flow @ 13,000	75 / 13.4	32 Final	60.6 / 21	-13	1.4	0.82 / 0.37	133	316L SS Gaskets to be Teflon envelope	Pipe for Coil / dimpledl tank jacket	N/A	N/A	316 SS clips & brackets for coil	137	2" Coil / dimpled approx .5" to 1" Jacket	150 lb RF Flng.	2" / 60 ft min	N/A	1
H-304	Lithium Hydroxide Heat Exchanger Coil & Jacket	10.4% LiOH Soln. / Syltherm 800	65 coil / 25 jacket	104,234 coil / 0 Jacket	573	Mixed Tank Entrained Flow @ 7,700	74 / 3.2	77 Final or maintain	60.6 / 20	-13	1.4	0.92 / 0.37	22	316L SS Gaskets to be Teflon envelope	Pipe for Coil / Full tank jacket	N/A	N/A	316 SS clips & brackets for coil	8	1.5 " Coil / approx 0.5" to 1" Jacket	150 lb RF Flng.	1.5" / 15 ft min	N/A	1
H-307	Lithium Hydroxide Solution Heat Exchanger	10.4% LiOH Soln. / Syltherm 800	38	123,000	573	75	74 / 3.2	77 Final or maintain	60.6 / 20	-13	1.0	0.92 / 0.37	27-34 sq ft	316L SS Gaskets to be Teflon envelope	Shell & Tube	N/A	N/A	N/A	50 sq ft	2"	150 lb RF Flng	N/A	4.5 ft to 6 ft long end to end, 12" diameter	1
H-404	Sodium Hydroxide Heat Exchanger Coil & Jacket	30% NaOH Soln. / Syltherm 800	65 coil / 25 jacket	251,531 coil / 62,883 Jacket	595	Mixed Tank Entrained Flow @ 7,700	83 / 12	77 Final or maintain	60.6 / 20	-13	1.4	0.85 / 0.37	55	316L SS Gaskets to be Teflon envelope	Pipe for Coil / Full tank jacket	N/A	N/A	316 SS clips & brackets for coil	25	1.5 " Coil / approx 0.5" to 1" Jacket	150 lb RF Flng.	1.5" / 32 ft min	N/A	1
H-504	Potassium Hydroxide Heat Exchanger Coil & Jacket	45% KOH Soln. / Syltherm 800	65 coil / 25 jacket	566,277 coil / 141,569 Jacket	339	Mixed Tank Entrained Flow @ 7,700	90 / 3.8	77 Final or maintain	60.6 / 20	-13	1.4	0.62 / 0.37	91	316L SS Gaskets to be Teflon envelope	Pipe for Coil / Full tank jacket	N/A	N/A	316 SS clips & brackets for coil	17	1.5 " Coil / approx 0.5" to 1" Jacket	150 lb RF Flng.	1.5" / 21 ft min	N/A	1
H-805	Heater	Syltherm 800	64	563886	N/A	30% KOH flow @ 102	81.7 / 6.1	-13 inlet / -0.4 outlet	0.073 / 0.0175	amb. (77 F)	amb. +10 F (87 F)	0.67 / 0.2375	90	316L SS tubes with aluminum fins Galv. Steel casing Gaskets to be Teflon envelope	Air (Fan) cooled alloy exchanger 31.3" L 55.5" W 55.5" H	5 HP TEFC	230-460/3/60	Epoxy Coated Base or 316 SS base	100	3" for Syltherm Side	150 lb RF Flng.	N/A	52.5" x 52.5"	1
C-800	Chiller System Air cooled unit with R-22refrig.; Screw compressor	Syltherm 800	Coolant/ Syltherm Coefficients by Vendor	Process Req: 1,160,000 btu/hr 100 Ton Unit Nominal	N/A	400	Outlet 61 / 22	N/A	Inlet Cond. 60 / 19	3.6 Inlet	-13 Outlet	Intet: 0.370 Outlet: 0.366	By Vendor	Exchanger & Air Cooled Condenser; CS / Galv. Steel	Coils	Air Cooled Units:	460/3/60	By Vendor	BY Vendor	4" or 6"	150 lb RF Flng.	N/A		1

amb.	Ambient Conditions	carb.	Carbon steel
cond.	condition	Flng.	Flanged
galv.	Galvanized	N/A	not applicable
psia	pounds per square inch (absolute)	soln.	Solution
RF	Raised Face (flange)	SS	Stainless Steel
TBD	To be determined	w/	with
w.c.	pressure in inches of water column		

CASE ENGINEERING, INC.
5925 Imperial Parkway, Suite 226 • Mulberry, FL 33860

EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018

REV: P2
DATE: 3/26/04

PUMPS

Number	Description	Service	Pump Description	Flow Rate (gpm)	Max. Head (ft w.c.)	Density (lb/cu ft) / Viscosity (cp)	Min. Suction Avail. (ft)	Min. / Max. Temperature (F)	Material of Construction	Speed (rpm)	Power (HP)	Motor Type & Frame	Volts/Phase/Freq.	Seal Type	Base plate	Impeller Dia.	Connections	Connection Type	BHP	QTY.
P-201	MOH Make-Up Transfer Pump	22.6% Alkali Mix	Centrifugal Pump	100	38 to 40	75 / 13.4	2	32 - 5	Wetted: TEFZEL ETFE, Gasket/O-Ring FEP	1750	3	TEFC 182TC	230-460/3/60	Magnetic Drive (No Seals) w/ Silicon Carbide bearings, shaft & sleeves	Channel Steel w/ Epoxy Paint	8" max.; Rated @ 6.7"	3" x 1.5"	150 lb RF Flng.	2.5 @ 100 gpm & 3.1 @ 140 gpm	1
P-301	Lithium Hydroxide Transfer Pump	10.4% LiOH Soln.	Progressive Cavity Pump	75	61 to 70	74 / 3.2	2	amb - 212	Wetted: 316 SS and EPDM stator; Cast Iron Body	Motor 1715 Gear Red 305	7.5	TEFC 213TC	230-460/3/60	PC Pump with single internal mechanical seal	Channel Steel w/ Epoxy Paint	N/A	4"x3"	150 lb RF Flng.	3.23	1
P-306	Lithium Hydroxide In-Line Mixing Pump	10.4% LiOH Soln.	High Shear rotary mixing pump	65 min	Assume No Head	74 / 3.2	2	amb - 212	Wetted 316SS 304SS Lantern Flg Teflon encapsulated silicone (TES)	3600 Inv. Duty 4:1 Sheaves 1.6 ratio 5800 drive speed	10	TEFC C-Face mount	230-460/3/60	IKA 2000 / 5 Model Pump with double mechanical cartridge seal Silicone Carbide (SC), SC, Teflon SS cart. & Carbon, SC Teflon SS cart.	SS Base plate with access panel for belt	N/A	1-1/2" Liquid inlet 1" solids inlet 1-1/2" Liquid outlet	150 lb RF Flng.	10	1
P-401	Sodium Hydroxide Transfer Pump	30% NaOH Soln.	Progressive Cavity Pump	75	66 to 70	83 / 12	2	amb. - 212	Wetted: 316 SS and EPDM stator; Cast Iron Body	Motor 1715 Gear Red 305	7.5	TEFC 213TC	230-460/3/60	PC Pump with single internal mechanical seal	Channel Steel w/ Epoxy Paint	N/A	4"x3"	150 lb RF Flng.	3.23	1
P-501	Potassium Hydroxide Transfer Pump	45% KOH Soln.	Progressive Cavity Pump	75	65 to 70	90 / 3.8	2	amb. - 212	Wetted: 316 SS and EPDM stator; Cast Iron Body	Motor 1715 Gear Red 305	7.5	TEFC 213TC	230-460/3/60	PC Pump with single internal mechanical seal	Channel Steel w/ Epoxy Paint	N/A	4"x3"	150 lb RF Flng.	3.23	1
P-701	Deionized Water Transfer Pump	100% DI Water	Centrifugal Pump	75	25 to 30	62.31 / .95	2	amb.	Wetted: TEFZEL ETFE, Gasket/O-Ring FEP	1750	3	TEFC 182TC	230-460/3/60	Magnetic Drive (No Seals) w/ Silicon Carbide shaft & sleeves	Channel Steel w/ Epoxy Paint	8" max.; Rated @ 6.25"	3" x 1.5"	150 lb RF Flng.	1.3 @ 75 gpm & 1.9 @ 121 gpm	1
P-702	Deionized Water Wash Pump	100% DI Water	Centrifugal Pump	75 -100	143 to 97	62.31 / .95	2	amb.	Wetted: TEFZEL ETFE, Gasket/O-Ring FEP	1750	15	TEFC 256TC	230-460/3/60	Magnetic Drive (No Seals) w/ Silicon Carbide bearings, shaft & sleeves	Channel Steel w/ Epoxy Paint	10.5" max.; Rated @ 10.5"	4" x 3"	150 lb RF Flng.	6 @ 100 gpm & 9 @ 200 gpm	1
P-801	MOH Chiller Pump	Syltherm 800	Centrifugal Pump	390	70	60 / 19-22	1	-13 to 4	Wetted: TEFZEL ETFE, Gasket/O-Ring FEP	1750	20	TEFC 256TC	230-460/3/60	Magnetic Drive (No Seals) w/ Silicon Carbide bearings, shaft & sleeves	Channel Steel w/ Epoxy Paint	10.5" max.; Rated @ "	4" X 3"	150 lb RF Flng.	12 Bhp @ 400 gpm & 16 @600 gpm	1

amb.	Ambient Conditions	soln.	Solution
est.	estimated value	SS	Stainless Steel
Flng.	Flanged	TEFC	Totally enclosed, fan cooled
max.	maximum	w/	with
N/A	not applicable	RF	Raised Face (flange)
psig	pounds per cubic foot (gauge)		

CASE ENGINEERING, INC.
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EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
MDA No.: 03-018

REV: P2
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TANKS, VESSELS & OTHER CONTAINERS

Number	Name	Service	Tank Description	Density (lb/cu ft) / Viscosity (cp)	Tank Min. / Max. Temperature (F)	Jacket Min. / Max. Temperature (F)	Material of Construction	Tank Internal Diameter (ft-inches)	Tangent to Tangent (ft-inches)	Btm. Tangent to Flat Top (ft-inches)	Batch Volume / Tank Volume w/ volume of lower head only(gallons)	Design Pressure (psig)	Design Temperature (F)	Connection Type	QTY.
T-200	MOH Make-Up Tank	22.6% Alkali Mix	Pickled and Passivated Low Pressure dimpled jacket vessel with top and bottom ASME dished heads with internal cooling coils (See H-204)	75 / 13.4	32 to 5	-13 to 1.4	Tank & Jacket: 316L SS with Teflon Enveloped Gaskets	7' – 0"	5' - 0"	N/A	1100 / 1644	Tank: 0 - 2 Jacket: 60	Tank: 250 Jacket: -13 to 250	150 lb RF Flng.	1
T-300	Lithium Hydroxide Dilution Tank	10.4% LiOH Soln.	ASME bottom & top heads with dimpled Jacket on sides and bottom with internal cooling coils (See H-304)	74 / 3.2	amb to 212	-13 to 1.4	Tank & Jacket: 316L SS with Teflon Enveloped Gaskets	5' – 0"	4' – 6"	N/A	573 / 736	Tank: 0 Jacket: 60	Tank: 250 Jacket: -13 to 250	150 lb RF Flng.	1
T-400	Sodium Hydroxide Dilution Tank	25% NaOH Soln.	ASME bottom & top heads with dimpled Jacket on sides and bottom with internal cooling coils (See H-404)	83 / 12	amb to 212	-13 to 1.4	Tank & Jacket: 316L SS with Teflon Enveloped	5' – 0"	4' – 6"	N/A	595 / 736	Tank: 0 Jacket: 60	Tank: 250 Jacket: -13 to 250	150 lb RF Flng.	1
T-500	Potassium Hydroxide Dilution Tank	40% KOH Soln.	ASME bottom & top heads with dimpled Jacket on sides and bottom with internal cooling coils (See H-504)	90 / 3.8	amb to 212	-13 to 1.4	Tank & Jacket: 316L SS with Teflon Enveloped Gaskets	5' – 0"	4' – 6"	N/A	339 / 736	Tank: 0 Jacket: 60	Tank: 250 Jacket: -13 to 250	150 lb RF Flng.	1
T-700	Deionized Water Storage Tank	100% DI Water	Conical bottom flat bolted top	62.31 / .95	amb. (approx 77 F)	N/A	Tank: 316L with Teflon coating and Teflon Enveloped Gaskets	7' - 0"	N/A	7' – 0"	1500 / 2075	Tank: 0	Tank: 120	150 lb RF Flng	1
SP-803	Chiller Centrifugal Air Separator	Syltherm 800 or 30% KOH Son.	Tank to remove air and large impurities from transfer lines (Weight = 250 lbs)	81.2 / 4.8	-13 / amb	N/A	Tank: Stainless Steel with Teflon Enveloped Gaskets	O.D. = 16" Length = 33" Skirt Height = 6"	N/A	N/A	Approx. 70	150	300	4" 150 lb RF Flng.	1
SP-804	Chiller Expansion Tank	Syltherm 800 or 30% KOH Son.	Tank to allow for thermal expansion of the Syltherm or KOH	81.2 / 4.8	-13 / amb	N/A	Tank: Stainless Steel with Teflon Enveloped Gaskets	(TBD)	(TBD)	(TBD)	(TBD)	60	240	1-1/2" 150 lb RF Flng.	1
V-1001	Air Receiver	Dry Air	ASME Code Vessel with dished heads top and bottom	0.073 / 0.0175	amb. (approx 77 F)	N/A	Carbon Steel with epoxy coat Horizontally mounted to compressor	25" Dia.; 27" from bottom of legs to top of tank	74.4" incl. Heads	N/A	120	150	240	2" - NPT	1

amb.	Ambient Conditions	OD	Outside diameter
approx	approximate	psig	pounds per square inch (gauge)
btm.	Bottom	RF	Raised Face (flange)
conn.	connection	sat.	saturated (regarding solute or dissolved gas in solution)
Dia.	Diameter	soln.	Solution
Flng.	Flanged	SS	Stainless Steel
N/A	not applicable	TBD	To be determined
w/	with		

MISC. EQUIPMENT & PACKAGE UNITS

Number	Name	Service	System Description	Flow Rate	Feed Water Specification	Density (lb/cu ft) / Viscosity (cp)	Min. / Max. Temp. (F)	Unit Dimensions	MOC	Speed (rpm)	Power (HP)	Motor Type & Frame	Volts/ Phase/ Freq.	Requirements	Other Features	Options	Conn.	Conn. Type	BHP	QTY.
DI-701	D.I. Water Filtration Unit	Potable water	Two 3.6 cu. Ft. Mixed DI Filter Modules and One 3.6 cu. Ft. Activated Carbon Module	10	Potable water @ ambient temperatures 15-50 psig pH 4-11 Free chlorine <0.02 ppm Max. turbidity 1 NTU SDI Rating = 3	62.31 / .95	50 - 113	36" Deep X 105" Long X 55" High	Modules To Be CPVC, PVC or Fiberglass	N/A	N/A	N/A	N/A	Supplying a stream of potable water adhering to Federal Primary and Secondary Drinking water standards, this system should produce 10 gpm of water having less than or equal to 25 umhos conductivity	A multi filter housing and two mixed DI beds will act as a pre-treatment unit	20", 5 micron prefilter, 20", 5 micron postfilter, conductivity alarm	3/4"	Main Process NPTM	N/A	1
K-1000	Air Compressor	Ambient Air	Rotary screw compressor	102 cfm @ 125 psig	N/A	0.073 / 0.018	123 to amb.	77.5" L 36" W 71" H	See Vendor Literature	Motor:1760	25	By Vendor	460/3/60	Ingersoll - Rand Model UP6-25-125: Capacity of 102 cfm @ 125 psig	120 gallon tank included with appropriate enclosure for outdoor service		1"	NPT	N/A	1

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EQUIPMENT SPECIFICATION LIST
PROJECT No.: 3160
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MISC. EQUIPMENT & PACKAGE UNITS

Number	Name	Service	System Description	Flow Rate	Feed Water Specification	Density (lb/cu ft) / Viscosity (cp)	Min. / Max. Temp. (F)	Unit Dimensions	MOC	Speed (rpm)	Power (HP)	Motor Type & Frame	Volts/ Phase/ Freq.	Requirements	Other Features	Options	Conn.	Conn. Type	BHP	QTY.
X-305	Bulk Bag Unloading System [for Lithium Hydroxide]	99.0% LiOH H2O Solid crystal	Bulk Bag Unloading Frame for Lithium Hydroxide	0.14 cfm min.	N/A	50 bulk density / N/A	amb / 105	Material Transfer & Storage Inc. 193" high, 66.5" square, monorail extends approx 117" from far side of unit See Drawing #: AESOCASEA	Main frame shall be heavy duty SS construction 1- SS discharging unit 1-2 ton Harrington chain hoist w/motorized trolley 1- SS lifting frame 1-bag massaging system 1-Bag spout seal system 1-Flo Lock slide gate valve (optional) 1-NEMA 4X control panel 1-304SS surge hopper and Roto-Disc valve 1-Load cell system 1-Premier rotary airlock valve	Hoist: 16 fpm with a 60 Hz motor drive Trolley: 40 fpm with a 60 Hz motor drive Rotary Airlock Valve: 3-30 rpm with a 60Hz motor drive	Hoist: 2.4 HP Trolley: 0.5 HP Rotary Valve: 1 HP	Hoist: TEFC By vendor Trolley: TENV By vendor Rotary Valve: TEFC Inverter Duty gear motor By vendor	Hoist: 230-460/ 3/60 Trolley: 230-460/ 3/60 Rotary Valve: 230-460/ 3/60	Unit takes up to 2 ton super sacks and lifts load so that contents can be delivered to a hopper and into a rotary valve for final dumping into a tank. Bolt down stationary outdoor use.		3-Polycarbonate 3/8" thick panels 48" high and removable. Mounted on three sides 40" above base of unit. Nickel diffused chain, SS hook, NEMA 4R pendant cord, SS chain container, SS side rollers, SS trolley wheels, custom CRT "Black-T" coating on hoist	N/A	N/A	N/A	1
X-405	Bulk Bag Unloading System [for Sodium Hydroxide]	96.6% NaoH No. 2 or No. 4 Flake	Bulk Bag Unloading Frame for Sodium Hydroxide	0.30 cfm min.	N/A	45 bulk density / N/A	amb / 105	Material Transfer & Storage Inc. 193" high, 66.5" square, monorail extends approx 117" from far side of unit See Drawing #: AESOCASEA	Main frame shall be heavy duty SS construction 1- SS discharging unit 1-2 ton Harrington chain hoist w/motorized trolley 1- SS lifting frame 1-bag massaging system 1-Bag spout seal system 1-Flo Lock slide gate valve (optional) 1-NEMA 4X control panel 1-304SS surge hopper and Roto-Disc valve 1-Load cell system 1-Premier rotary airlock valve	Hoist: 16 fpm with a 60 Hz motor drive Trolley: 40 fpm with a 60 Hz motor drive Rotary Airlock Valve: 3-30 rpm with a 60Hz motor drive	Hoist: 2.4 HP Trolley: 0.5 HP Rotary Valve: 1 HP	Hoist: TEFC By vendor Trolley: TENV By vendor Rotary Valve: TEFC Inverter Duty gear motor By vendor	Hoist: 230-460/ 3/60 Trolley: 230-460/ 3/60 Rotary Valve: 230-460/ 3/60	Unit takes up to 2 ton super sacks and lifts load so that contents can be delivered to a hopper and into a rotary valve for final dumping into a tank. Bolt down stationary outdoor use.		3-Polycarbonate 3/8" thick panels 48" high and removable. Mounted on three sides 40" above base of unit. Nickel diffused chain, SS hook, NEMA 4R pendant cord, SS chain container, SS side rollers, SS trolley wheels, custom CRT "Black-T" coating on hoist	N/A	N/A	N/A	1

MISC. EQUIPMENT & PACKAGE UNITS

Number	Name	Service	System Description	Flow Rate	Feed Water Specification	Density (lb/cu ft) Viscosity (cp)	Min. / Max. Temp. (F)	Unit Dimensions	MOC	Speed (rpm)	Power (HP)	Motor Type & Frame	Volts/ Phase/ Freq.	Requirements	Other Features	Options	Conn.	Conn. Type	BHP	QTY.
X-505	Bulk Bag Unloading System [for Potassium Hydroxide]	90.0% KOH No. 2 or No. 4 Flake	Bulk Bag Unloading Frame for Potassium Hydroxide	0.3 cfm min.	N/A	45 bulk density / N/A	amb / 105	Material Transfer & Storage Inc. 193" high, 66.5" square, monorail extends approx 117" from far side of unit See Drawing #: AESOCASEA	Main frame shall be heavy duty SS construction 1- SS discharging unit 1-2 ton Harrington chain hoist w/motorized trolley 1- SS lifting frame 1-bag massaging system 1-Bag spout seal system 1-Flo Lock slide gate valve (optional) 1-NEMA 4X control panel 1-304SS surge hopper and Roto-Disc valve 1-Load cell system 1-Premier rotary airlock valve	Hoist: 16 fpm with a 60 Hz motor drive Trolley: 40 fpm with a 60 Hz motor drive Rotary Airlock Valve: 3-30 rpm with a 60Hz motor drive	Hoist: 2.4 HP Trolley: 0.5 HP Rotary Valve: 1 HP	Hoist: TEFC By vendor Trolley: TENV By vendor Rotary Valve: TEFC Inverter Duty gear motor By vendor	Hoist: 230-460/ 3/60 Trolley: 230-460/ 3/60 Rotary Valve: 230-460/ 3/60	Unit takes up to 2 ton super sacks and lifts load so that contents can be delivered to a hopper and into a rotary valve for final dumping into a tank. Bolt down stationary outdoor use.		3-Polycarbonate 3/8" thick panels 48" high and removable. Mounted on three sides 40" above base of unit. Nickel diffused chain, SS hook, NEMA 4R pendant cord, SS chain container, SS side rollers, SS trolley wheels, custom CRT "Black-T" coating on hoist	N/A	N/A	N/A	1

amb.	Ambient Conditions	SS	Stainless Steel
cfm	cubic feet per minute	w/	with
D.I.	Deionized water	umhos	micro mhos (unit of conductivity)
Flng	Flanged		
I.D.	Internal diameter		
N/A	not applicable		
NPTF	National Pipe Thread (female)		
NPTM	National Pipe Thread (male)		
NTU	nephelometer turbidity unit		
ppm	parts per million (or mg/l)		
psig	pounds per square inch (gauge)		
PVC	polyvinyl chloride		
RF	Raised Face (flange)		
R/O	Reverse Osmosis		
SDI	Silt Density Index		
cfm	cubic feet per minute		

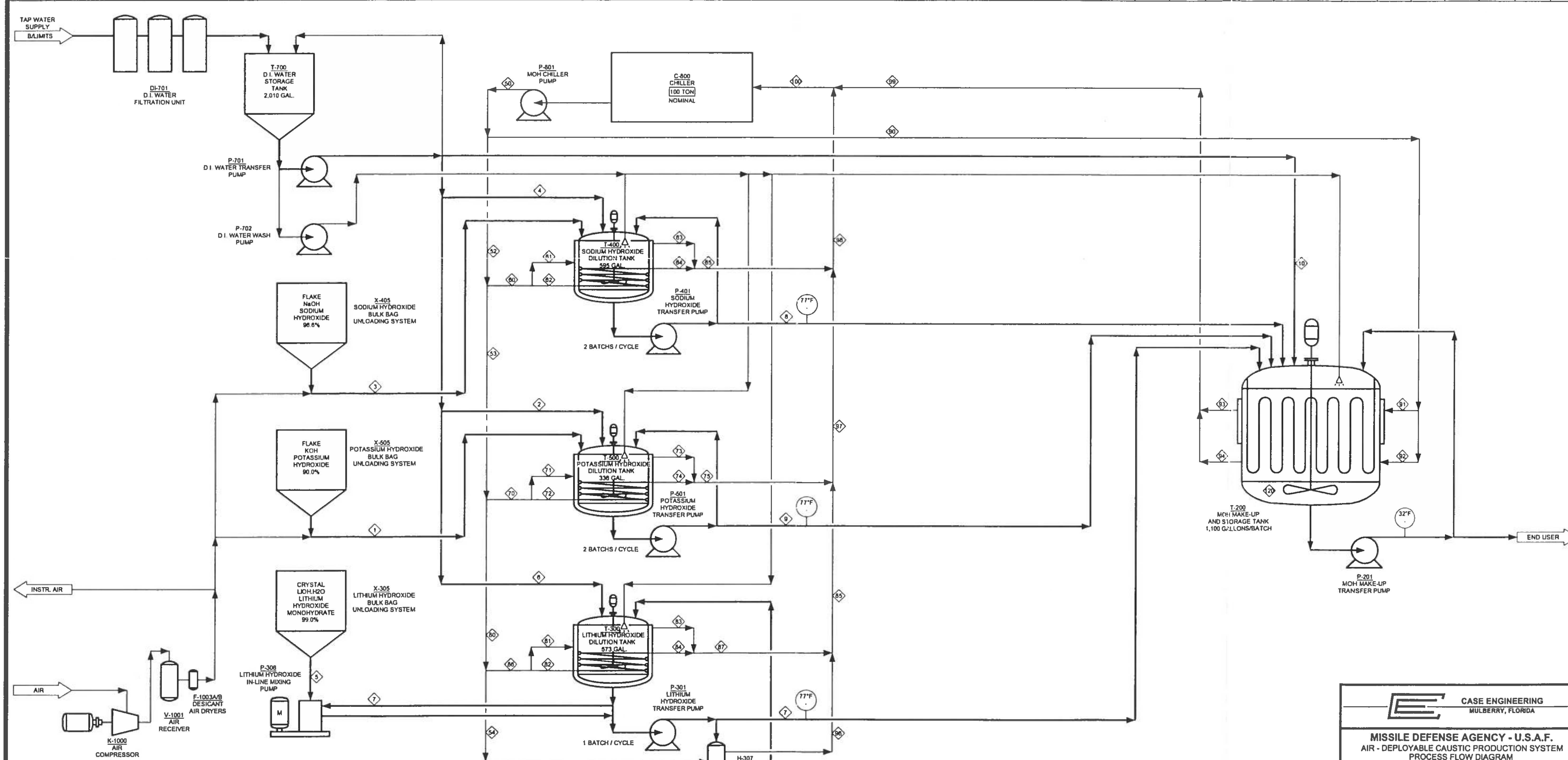
SECTION

5

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CHEMICAL	DRY KOH 90%	DEMIN. WATER 100%	DRY NaOH 96.6%	DEMIN. WATER 100%	DEMIN. LIOH H2O 99%	DEMIN. WATER 100%	LIOH SOLUTION 18%	NaOH SOLUTION 30%	KOH SOLUTION 45%	DEMIN. WATER 100%	MOH SOLUTION 75.8%	.	.	.	.	.	.	.	.	.	.
FLOW (GPM) [ft³/MIN]	[0.30]	75	[0.30]	75	[0.14]	75	75	75	75	75	100	.	.	.	.	.	.	.	.	.	.
MASS (lb/BATCH)	2,050	2,050	2,042	4,534	1,045	4,624	5,669	3,288	2,050	28	11,036	.	.	.	.	.	.	.	.	.	.
TEMPERATURE (°F)	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0	77.0	32.0	.	.	.	.	.	.	.	.	.	.
XFER/RES TIME (MIN.)	150	3.3	150	7.2	150	7.4	7.6	4.0	2.3	0.05	11.0	.	.	.	.	.	.	.	.	.	.
DENSITY (lb/ft³)	45.0	62.42	45.0	62.42	49.94	62.42	73.97	82.72	90.54	62.42	75.0	.	.	.	.	.	.	.	.	.	.
MW (lb/lbmol)	46.8	18.0	39.8	18.0	41.4	18.0	18.5	21.7	26.0	18.0	20.5	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (BTU/lb°F)	.	0.998	.	0.998	.	0.998	0.920	0.845	0.617	0.998	0.821	.	.	.	.	.	.	.	.	.	.
VISCOSITY (cp)	N/A	1.00	N/A	1.00	N/A	1.00	3.192	12.00	3.750	1.00	13.42	.	.	.	.	.	.	.	.	.	.

STREAM NO.	50	.	52	53	54	.	60	61	62	63	64	65	.	70	71	72	73	74	75	.
CHEMICAL	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.
FLOW (GPM) [ft³/MIN]	388	.	202	132	40	.	71	19	51	19	52	71	.	91	25	66	25	67	92	.
MASS (lb/BATCH)	190,066	.	99,013	64,421	19,697	.	34,591	9,450	25,141	9,450	25,141	34,591	.	44,725	12,219	32,506	12,219	32,506	44,725	.
TEMPERATURE (°F)	-13.0	.	-13.0	-13.0	-13.0	.	-13.0	-13.0	-13.0	1.4	8.6	6.6	.	-13.0	-13.0	-13.0	1.4	8.6	6.6	.
XFER/RES TIME (MIN.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
DENSITY (lb/ft³)	61.0	.	61.0	61.0	61.0	.	61.0	61.0	61.0	60.6	60.3	60.4	.	61.0	61.0	61.0	60.6	60.3	60.4	.
MW (lb/lbmol)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (BTU/lb°F)	0.366	.	0.366	0.366	0.366	.	0.366	0.366	0.366	0.369	0.371	0.371	.	0.366	0.366	0.366	0.369	0.371	0.371	.
VISCOSITY (cp)	22	.	22	22	22	.	22	22	22	20	18	19	.	22	22	22	20	18	19	.

STREAM NO.	80	81	82	83	84	85	86	87	90	91	92	93	94	.	96	97	98	99	100
CHEMICAL	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM
FLOW (GPM) [ft³/MIN]	40	0	0	0	0	41	0	0	186	93	93	94	94	.	41	133	204	187	392
MASS (lb/BATCH)	19,697	0	0	0	0	19,697	0	0	91,053	45,527	45,527	45,527	45,527	.	19,697	64,421	99,013	91,053	190,066
TEMPERATURE (°F)	-13.0	-13.0	-13.0	1.4	1.4	1.4	.	1.4	-13.0	-13.0	-13.0	1.4	1.4	.	1.4	5.0	5.6	1.4	3.6
XFER/RES TIME (MIN.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
DENSITY (lb/ft³)	61.0	61.0	61.0	60.6	60.6	60.6	.	60.6	61.0	61.0	61.0	60.6	60.6	.	60.6	60.4	60.4	60.6	60.5
MW (lb/lbmol)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (BTU/lb°F)	0.366	0.366	0.366	0.369	0.369	0.369	.	0.369	0.366	0.366	0.366	0.369	0.369	.	0.369	0.370	0.370	0.369	0.370
VISCOSITY (cp)	22	22	22	20	20	20	.	20	22	22	22	20	20	.	20	19	19	20	19



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REFERENCE DRAWINGS				

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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CASE ENGINEERING
MULBERRY, FLORIDA

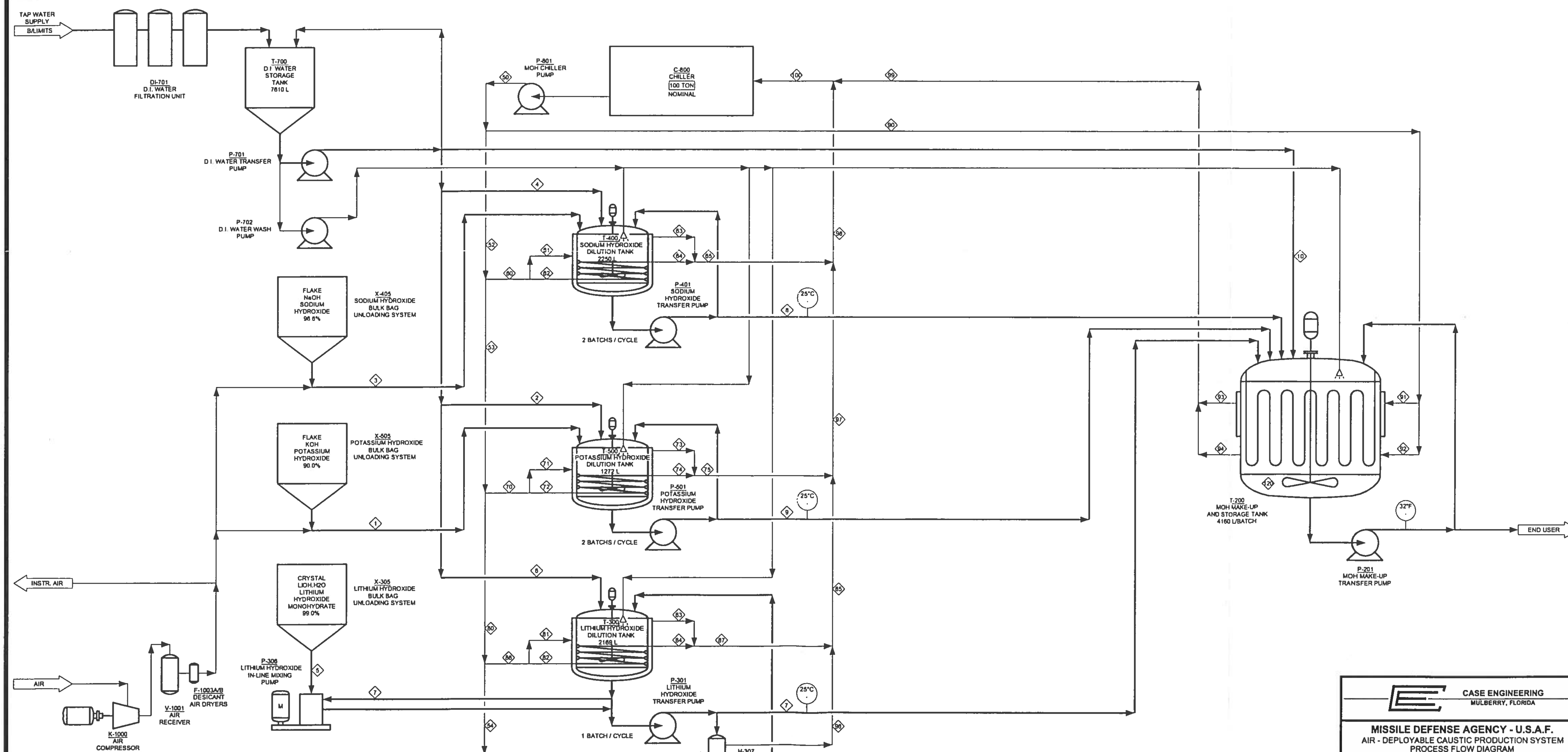
MISSILE DEFENSE AGENCY - U.S.A.F.
AIR - DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PROCESS FLOW DIAGRAM

DRAWN BY	MCM	20MAR02	DSGN. BY	JFS	19MAR02
CHECKED BY	.	.	DWG. SCALE	NONE	
APPROVED BY	.	.	PLOT SCALE	1 = 1	
CLIENT APPVL	.	.	DRAWING NO.		REV.
RMF +3160FM001 +03-26-04 @ 07.46			3160-FM-001		P0

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CHEMICAL	DRY KOH 90%	DEMIN. WATER 100%	DRY NaOH 98.6%	DEMIN. WATER 100%	DEMIN. LIOH H2O 99%	DEMIN. WATER 100%	LIOH SOLUTION 18%	NaOH SOLUTION 30%	KOH SOLUTION 45%	DEMIN. WATER 100%	MOH SOLUTION 75.8%	.	.	.	.	.	.	.	.	.	.
FLOW (LPM) [m³/MIN]	[0.009]	284	[0.009]	284	[0.004]	284	284	284	284	284	379	.	.	.	.	.	.	.	.	.	.
MASS (kg/BATCH)	930	930	926	2057	474	2097	2571	1492	930	13	5006	.	.	.	.	.	.	.	.	.	.
TEMPERATURE (°C)	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	0.0	.	.	.	.	.	.	.	.	.	.
XFER/RES TIME (MIN.)	150	3.3	150	7.2	150	7.4	7.6	4.0	2.3	0.0	11.0	.	.	.	.	.	.	.	.	.	.
DENSITY (g/cm³)	0.7	1.0	0.7	1.0	0.8	1.0	1.2	1.3	1.5	1.0	1.2	.	.	.	.	.	.	.	.	.	.
MW (kg/kgmol)	46.8	18.0	39.8	18.0	41.4	18.0	18.5	21.7	28.0	18.0	20.5	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (J/g°c)	0.0	4.2	0.0	4.2	0.0	4.2	3.8	3.5	2.6	4.2	3.4	.	.	.	.	.	.	.	.	.	.
VISCOSITY (cp)	N/A	1.00	N/A	1.00	N/A	1.00	3.4	11.00	3.5	1.00	0.0	.	.	.	.	.	.	.	.	.	.

STREAM NO.	50	.	52	53	54	.	60	61	62	63	64	65	.	70	71	72	73	74	75	.
CHEMICAL	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.
gallons/batch LPM	1470	.	766	498	152	.	268	73	194	74	197	270	.	346	94	251	95	254	349	.
MASS (kg/BATCH)	86,212	.	44,911	29,221	8,934	.	15,690	4,287	11,404	4,287	11,404	15,690	.	20,287	5,542	14,744	5,542	14,744	20,287	.
TEMPERATURE (°C)	-25.0	.	-25.0	-25.0	-25.0	.	-25.0	-25.0	-25.0	-17.0	-13.0	-14.1	.	-25.0	-25.0	-25.0	-17.0	-13.0	-14.1	.
XFER/RES TIME (MIN.)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
DENSITY (g/cm³)	0.976	.	0.976	0.976	0.976	.	0.976	0.976	0.976	0.969	0.966	0.967	.	0.976	0.976	0.976	0.969	0.966	0.967	.
MW (kg/kg mol)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (J/g°C)	1.5	.	1.5	1.5	1.5	.	1.5	1.5	1.5	1.5	1.6	1.6	.	1.5	1.5	1.5	1.5	1.6	1.6	.
VISCOSITY (cp)	22	.	22	22	22	.	22	22	22	20	18	19	.	22	22	22	20	18	19	.

STREAM NO.	80	81	82	83	84	85	86	87		90	91	92	93	94	.	96	97	98	99	100
CHEMICAL	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM		COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	.	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM	COOLANT 100% SYLTHERM
gallons/batch LPM	152	0	0	0	0	153	0	0		704	352	352	355	355	.	153	503	773	709	1483
MASS (kg/BATCH)	8,934	0	0	0	0	8,934	0	0		41,301	20,650	20,650	20,650	20,650	.	8,934	29,221	44,911	41,301	86,212
TEMPERATURE (°C)	-25.0	-25.0	-25.0	-17.0	-17.0	-17.0	.	1.4		-25.0	-25.0	-25.0	-17.0	-17.0	.	-17.0	-15.0	-14.7	-17.0	-15.8
XFER/RES TIME (MIN.)	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.
DENSITY (g/cm³)	0.976	0.976	0.976	0.969	0.969	0.969	.	60.6		0.976	0.976	0.976	0.969	0.969	.	0.969	0.967	0.967	0.969	0.968
MW (kg/kg mol)	.	.	.	.	.	.	.	.		.	.	.	.	.	.	.	.	.	.	.
SPECIFIC HEAT (J/g°C)	1.5	1.5	1.5	1.5	1.5	1.5	.	0.369		1.5	1.5	1.5	1.5	1.5	.	1.5	1.5	1.5	1.5	1.5
VISCOSITY (cp)	22	22	22	2.0	20	20	.	20		22	22	22	20	20	.	20	19	19	20	19



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REFERENCE DRAWINGS		

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY - U.S.A.F.
AIR - DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PROCESS FLOW DIAGRAM

DRAWN BY	MCM	20MAR02	DSGN. BY	JFS 19MAR02
CHECKED BY	.	.	DWG. SCALE	NONE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-FM-002	REV. P0
RMF •3160FM002 •03-26-04 @ 07:47				

GENERAL SYMBOLS

(NORMALLY CLOSED) (NORMALLY OPEN) BALL VALVE SEE NOTE 1	CHECK VALVE	PRESSURE SAFETY RELIEF VALVE
(CLOSED) (OPEN) GLOBE VALVE	(CLOSED) (OPEN) NEEDLE VALVE	PNEUMATIC OPERATED SPRING RETURN VALVE
	I/P CONTROL VALVE	BAG FILTER
PI CHEMICAL SEAL	CONSERVATION VENT	SP X SPECIALITY ITEM
S SOLENOID ACTUATED VALVE	P&ID DRAWING CONNECTORS FOR PROCESS LINES, UTILITY LINES AND LINES FROM BATTERY LIMITS	MAIN PROCESS LINE
FLEXHOSE	PNEUMATIC LINE	NON-PROCESS OR UTILITY LINE
ELECTRIC LINE	SOFTWARE LINK	REDUCER
SIMPLEX STRAINER	CAP	INS INSULATED PIPE
FLANGED NOZZLE	TO ATMOS. VENT	SAMPLE CONTAINMENT
CENTRIFUGAL PUMP	PROGRESSIVE CAVITY PD PUMP	IN-LINE SOLIDS MIXING PUMP
HAND ADJUSTABLE PRESSURE REGULATOR	PRESSURE REGULATOR	BACK PRESSURE REGULATOR
HOSE CONNECTION	ATMOSPHERIC VENT	C INSULATION
AGITATOR	FLUSH BOTTOM MOUNT VALVE	HIGH PRESSURE SPRAY BALL
AIR ACTUATED PISTON	DOUBLE ACTING GATE VALVE	M ROTARY VALVE

INSTRUMENT SYMBOLS

XX NNNN FIELD MOUNTED ACCESSIBLE DISCRETE INSTRUMENT	XX NNNN INACCESSIBLE PLC-BASED LOGIC	XX NNNN ACCESSIBLE SHARED DISPLAY/CONTROL ON PLC OPERATOR INTERFACE
(V) XX NNNN VENDOR SUPPLIED INSTRUMENT	IAS INSTRUMENT AIR (PIPE/TUBE)	RO NNNN RESTRICTING ORIFICE
FI NNNN IN-LINE FIELD FLOW INDICATOR	IAS VENDOR SUPPLIED INSTRUMENT AIR (PIPE/TUBE)	

EQUIPMENT NUMBER IDENTIFICATION

X-XXXX
- SEQUENTIAL NUMBER
- EQUIPMENT TYPE

EQUIPMENT TYPES

A - AGITATORS
C - CHILLERS
F - FILTERS
H - HEAT EXCHANGERS
K - COMPRESSORS
M - MOTORS/DRIVERS
P - PUMPS
R - REACTORS
S - SEPARATORS
T - TANKS (NON-CODE)
U - PACKAGE UNIT DESIGNATION
V - VESSELS (CODED)
X - EQUIPMENT ASSOCIATED WITH STRUCTURE/MATERIAL UNLOADING
Z - MISC. PROCESS EQUIPMENT

LINE NUMBER IDENTIFICATION

X - YYY - XXXX - XZYY - XY
- INSULATION/TRACING
- MATERIAL SPECIFICATION DESIGNATION (NOTE 3)
- LINE NUMBER (NOTE 2)
- SERVICE DESIGNATION (NOTE 6)
- LINE SIZE (NOTE 4)

2. LINE NUMBER - SEQUENTIAL LINE NUMBER

3. PIPING MATERIAL SPECIFICATION

4. LINE SIZE - NOMINAL PIPING DIAMETER OF THE LINE IN INCHES, WHERE SPECIFIED TUBING WILL BE O.D.

5. INSULATION/TRACING

HT - HEAT TRACED

6. SERVICE DESIGNATIONS

PROCESS

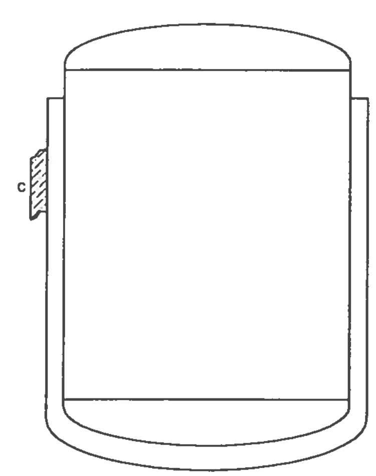
LH - LITHIUM HYDROXIDE
SH - SODIUM HYDROXIDE
KH - POTASSIUM HYDROXIDE
MOH - MIXED ALKALI SOLUTION

UTILITIES

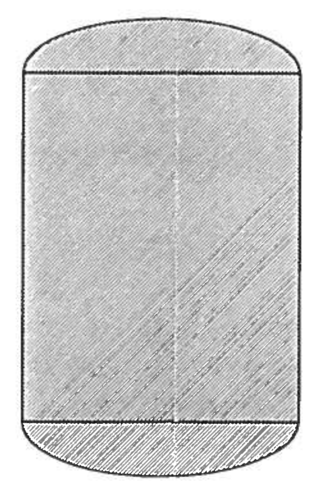
CS - CHILLER SOLUTION SUPPLY (SYLTHERM 800)
CR - CHILLER SOLUTION RETURN (SYLTHERM 800)
WDI - DEIONIZED PROCESS WATER
PWW - PROCESS WASTE WATER
IA - INSTRUMENT AIR

MISCELLANEOUS ABBREVIATIONS

FC - FAIL CLOSED
FO - FAIL OPEN
PSE - EXPLOSION RELIEF DEVICE
IAS - INSTRUMENT AIR SUPPLY
MW - MANWAY
HH - HANDHOLE
NC - NORMALLY CLOSED
NO - NORMALLY OPEN
SW - SEWER
LPD - LOW POINT DRAIN
HPV - HIGH POINT VENT
V - VENDOR FURNISHED
U.O.N.-UNLESS OTHERWISE NOTED



INSULATED/JACKETED TANK



TANKS AND INTERNAL EQUIPMENT TO BE PICKLED AND PASSIVATED

GENERAL NOTES:

1. ALL BALL VALVES ARE TO BE VENTED TO SUPPLY SIDE.
2. V-NOTCH VALVES ARE SPECIALTY VALVES NOTED ON DIAGRAMS
3. ON/OFF VALVE NOMENCLATURE

INDICATES A PLC SIGNAL TO A SOLENOID ASSOCIATED WITH VALVE "ZV"

THE SOLENOID ALSO BEARS THE TAG. "ZY-XXXX".

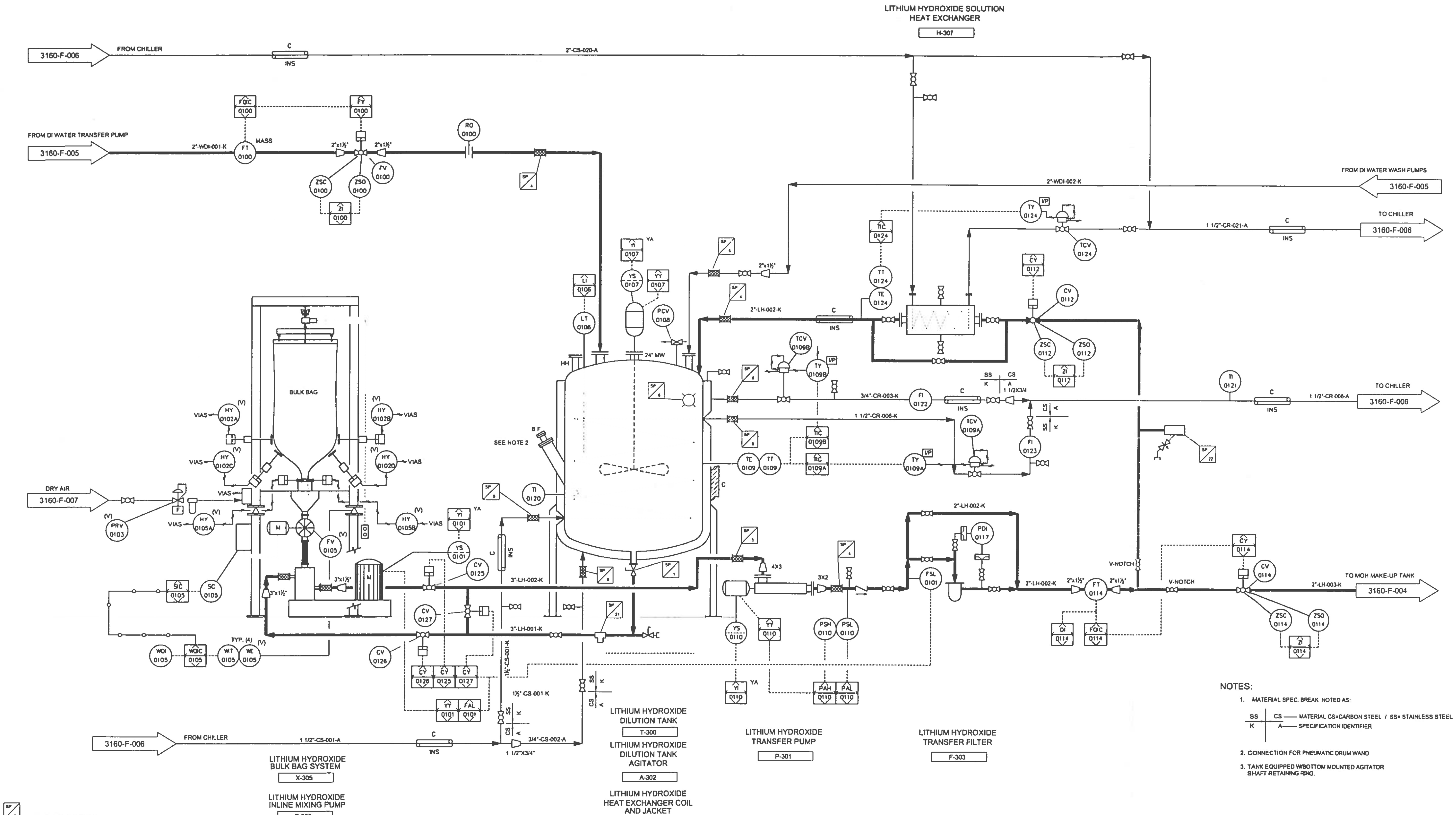
REFERENCE DRAWINGS

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR-DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION LEAD SHEET

DRAWN BY	RMF	25MAR04	DSGN. BY	
CHECKED BY			DWG. SCALE	FULL SIZE
APPROVED BY			PLOT SCALE	1 = 1
CLIENT APPVL			DRAWING NO. 3160-F-000	REV. P0



NOTES:

1. MATERIAL SPEC. BREAK NOTED AS:

   SS | CS — MATERIAL CS=CARBON STEEL / SS= STAINLESS STEEL
   K | A — SPECIFICATION IDENTIFIER

2. CONNECTION FOR PNEUMATIC DRUM WAND

3. TANK EQUIPPED W/BOTTOM MOUNTED AGITATOR SHAFT RETAINING RING.

SP 1 — FLUSH BOTTOM VALVE

SP 21 — SIMPLEX STRAINER W/ 1/2" PERF. BASKET ALL SS CONSTRUCTION AND FLANGED ENDS HAYWARD MODEL 72 OR EQUAL.

SP 3 — 3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).

SP 4 — 2" 150# FLANGED X 12" F/F FLEX JOINT (BRAIDED 316L SS).

SP 5 — 1 1/2" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).

SP 6 — 3/4" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).

SP 8 — 1 1/2" SPRAY BALL 316L SS SPRAYING SYSTEMS CO. MODEL NO. 8353-1/4-GG10 OR EQUAL

SP 22 — 316 SS SAMPLE VALVE (PCC SAFESAMP ISV-B SERIES) 150# FLANGED W/DEADMAN LEVER AND 90° ADAPTER WITH METAL SAFETY BASKET (GL 45)

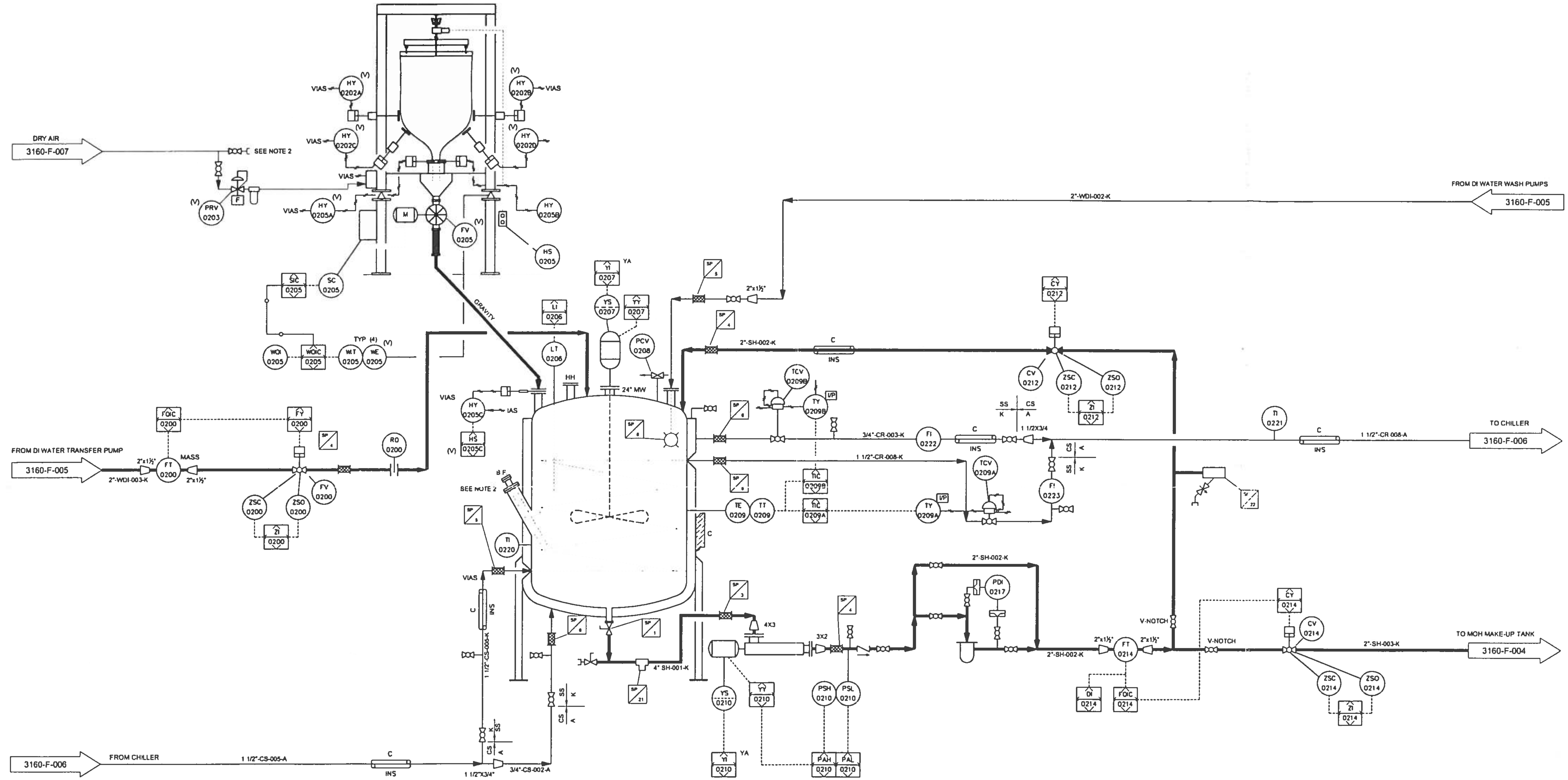
REFERENCE DRAWINGS

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
LITHIUM HYDROXIDE DILUTION

DRAWN BY	RMF	25AUG03	DSGN. BY	
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO.	REV.
RMF =3160F001	=03-25-04 @ 10:43		3160-F-001	Po



SODIUM HYDROXIDE BULK BAG SYSTEM
X-405

SODIUM HYDROXIDE DILUTION TANK
T-400

SODIUM HYDROXIDE DILUTION TANK AGITATOR
A-402

SODIUM HYDROXIDE HEAT EXCHANGER COIL AND JACKET
H-404

SODIUM HYDROXIDE TRANSFER PUMP
P-401

SODIUM HYDROXIDE TRANSFER FILTER
F-403

SP 1	FLUSH BOTTOM VALVE
SP 21	SIMPLEX STRAINER W/ 1/2" PERF. BASKET ALL SS CONSTRUCTION AND FLANGED ENDS HAYWARD MODEL 72 OR EQUAL.
SP 3	3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).
SP 4	2" 150# FLANGED X 12" F/F FLEX JOINT (BRAIDED 316L SS).
SP 5	1 1/2" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).
SP 6	3/4" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).
SP 7	1/2" X LENGTH AS REQ'D. 1/2" MPT BOTH ENDS CHEM HOSE
SP 8	1 1/2" SPRAY BALL 316L SS SPRAYING SYSTEMS CO. MODEL NO. 6353-1/4-GG10 OR EQUAL
SP 22	316 SS SAMPLE VALVE (PCC SAFESAMP ISV-B SERIES) 150# FLANGED WIDEADMAN LEVER AND 90° ADAPTER WITH METAL SAFETY BASKET (GL 45)

NOTES:

1. MATERIAL SPEC. BREAK NOTED AS:
   SS | CS —— MATERIAL CS=CARBON STEEL / SS= STAINLESS STEEL
   K | A —— SPECIFICATION IDENTIFIER
2. CONNECTION FOR PNEUMATIC DRUM WAND
3. TANK EQUIPPED W/BOTTOM MOUNTED AGITATOR SHAFT RETAINING RING.

REFERENCE DRAWINGS

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
SODIUM HYDROXIDE DILUTION

DRAWN BY	RMF	25AUG03	DSGN. BY	
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-F-002	REV. Po
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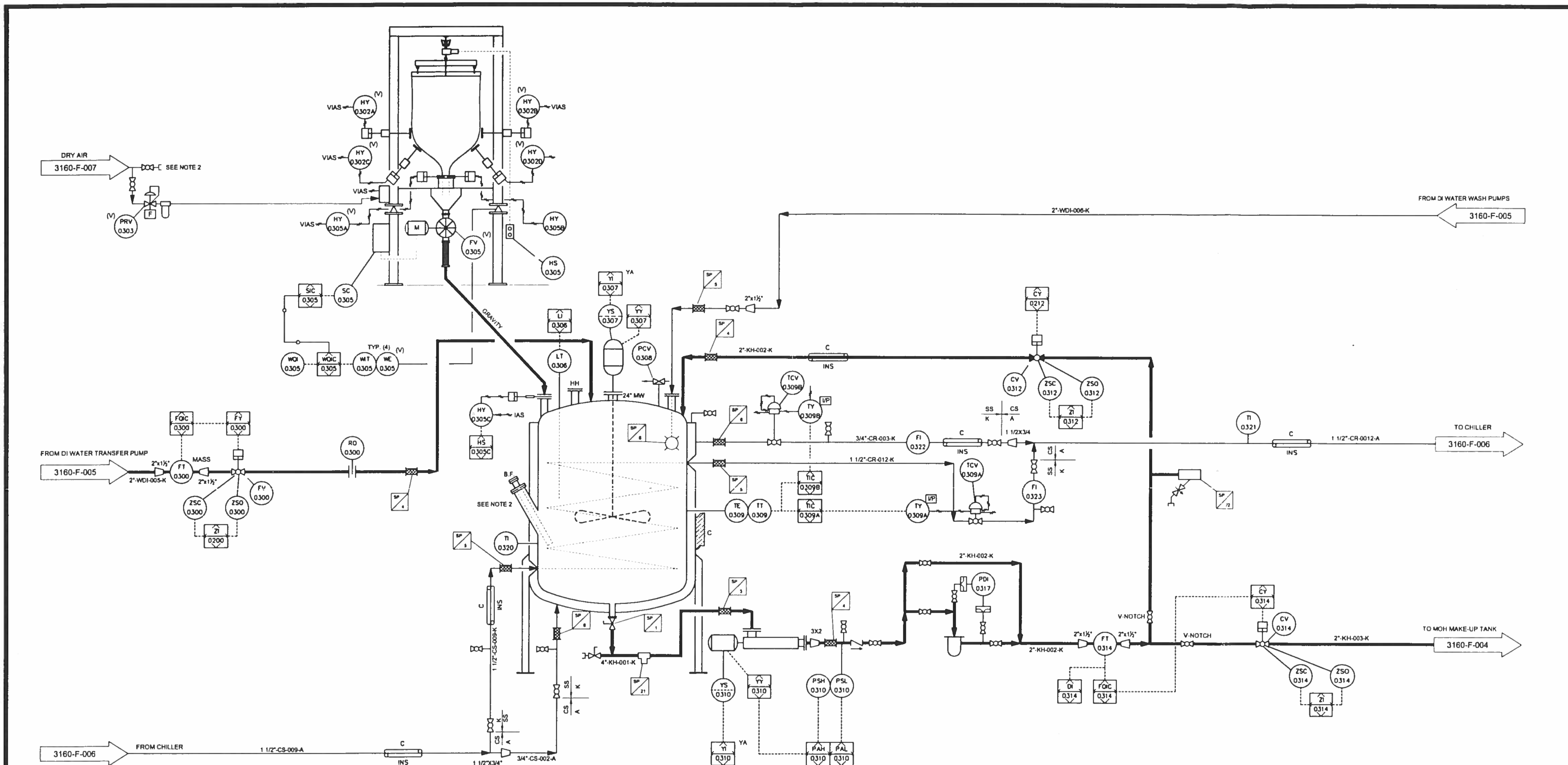

SP 1	FLUSH BOTTOM VALVE
SP 21	SIMPLEX STRAINER W/ 1/2" PERF. BASKET ALL SS CONSTRUCTION AND FLANGED ENDS HAYWARD MODEL 72 OR EQUAL.
SP 3	3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).
SP 4	2" 150# FLANGED X 12" F/F FLEX JOINT (BRAIDED 316L SS).
SP 5	1 1/2" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).
SP 6	3/4" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).
SP 7	1/2" X LENGTH AS REQ'D. 1/2" MPT BOTH ENDS CHEM HOSE
SP 8	1 1/2" SPRAY BALL 316L SS SPRAYING SYSTEMS CO. MODEL NO. 6353-1/4-GG10 OR EQUAL
SP 22	316 SS SAMPLE VALVE (PCC SAFESAMP ISV-B SERIES) 150# FLANGED W/DEADMAN LEVER AND 90° ADAPTER WITH METAL SAFETY BASKET (GL 45)

POTASSIUM HYDROXIDE BULK BAG SYSTEM
X-505

POTASSIUM HYDROXIDE DILUTION TANK
T-500

POTASSIUM HYDROXIDE DILUTION TANK AGITATOR
A-502

POTASSIUM HYDROXIDE HEAT EXCHANGER COIL AND JACKET
H-504

POTASSIUM HYDROXIDE TRANSFER PUMP
P-501

POTASSIUM HYDROXIDE TRANSFER FILTER
F-503

NOTES:

1. MATERIAL SPEC. BREAK NOTED AS:
   SS | CS — MATERIAL CS=CARBON STEEL / SS= STAINLESS STEEL
   K | A — SPECIFICATION IDENTIFIER
2. CONNECTION FOR PNEUMATIC DRUM WAND
3. TANK EQUIPPED W/BOTTOM MOUNTED AGITATOR SHAFT RETAINING RING.

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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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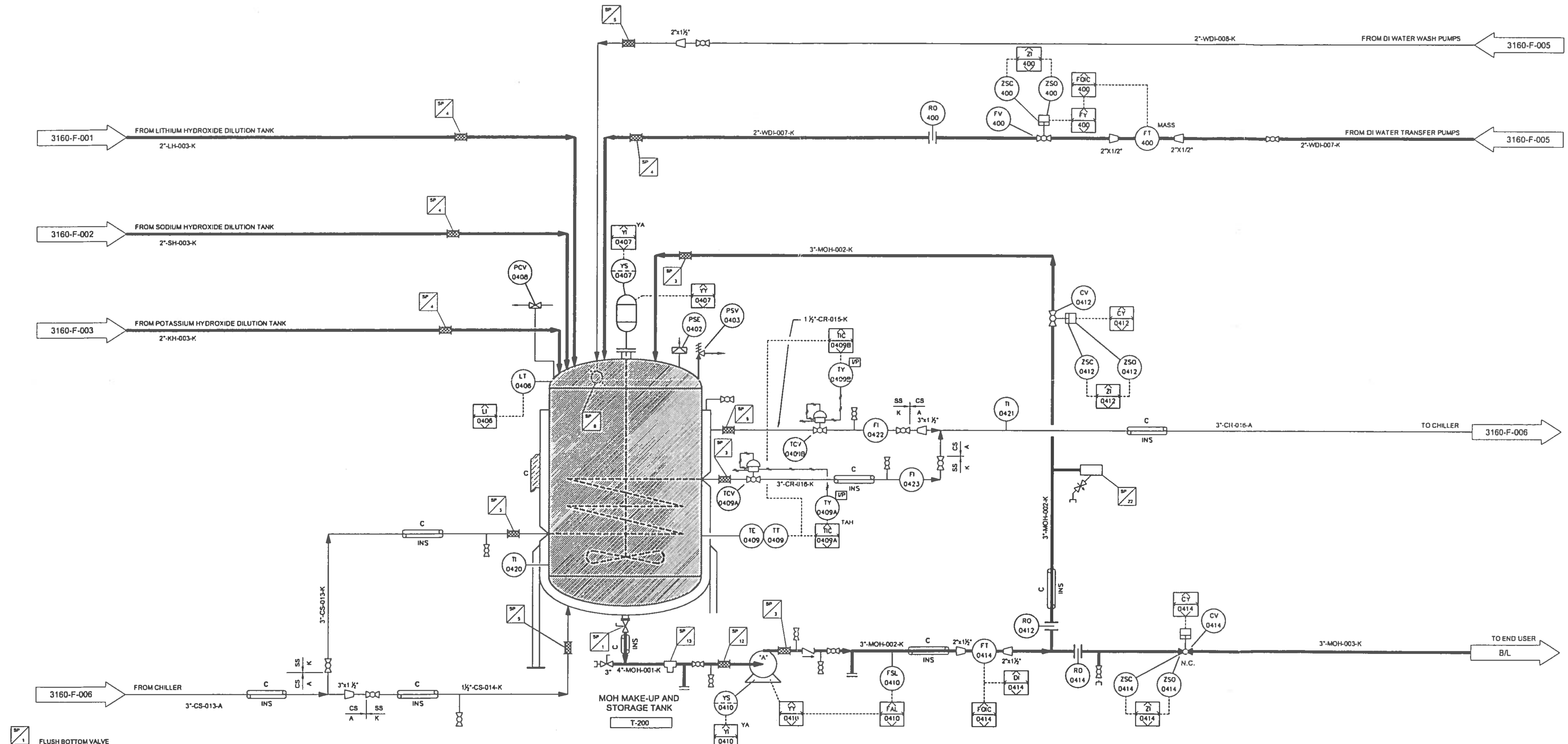
CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
POTASSIUM HYDROXIDE DILUTION

DRAWN BY	RMF	25AUG03	DSGN. BY	.
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-F-003	REV. Po
RMF +3160F003	+03-25-04 @ 10:52			



MOH MAKE-UP AND STORAGE TANK

T-200

MOH MAKE-UP TANK AGITATOR

A-202

MOH HEAT EXCHANGER COIL AND JACKET

H-204

MOH MAKE-UP TRANSFER PUMP

P-201

SP 1 — FLUSH BOTTOM VALVE

SP 3 — 3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).

SP 4 — 2" 150# FLANGED X 12" F/F FLEX JOINT (BRAIDED 316L SS).

SP 5 — 1 1/2" X 12" END/END MPT FLEX JOINT (BRAIDED 316L SS).

SP 8 — 1 1/2" SPRAY BALL 316L SS SPRAYING SYSTEMS CO. MODEL NO. 6353-1/4-GG10 OR EQUAL

SP 12 — 4" 150# FLANGED X 24" F/F FLEX JOINT (BRAIDED 316L SS).

SP 13 — 4" SIMPLEX STRAINER W/ 1/32"PERF. BASKET ALL SS CONSTRUCTION AND FLANGED ENDS HAYWARD MODEL 72 OR EQUAL.

SP 22 — 316 SS SAMPLE VALVE (PCC SAFESAMP ISV-B SERIES) 150# FLANGED W/DEADMAN LEVER AND 90° ADAPTER WITH METAL SAFETY BASKET (GL 45)

NOTES:

1. MATERIAL SPEC. BREAK NOTED AS:
   SS | CS —— MATERIAL CS=CARBON STEEL / SS= STAINLESS STEEL
   K | A —— SPECIFICATION IDENTIFIER

2. TANK EQUIPPED W/BOTTOM MOUNTED AGITATOR SHAFT RETAINING RING.

REFERENCE DRAWINGS

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.

AIR DEPLOYABLE CAUSRIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
MOH MAKE-UP TANK

DRAWN BY	RMF	10OCT03	DSGN. BY	
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-F-004	REV. Po
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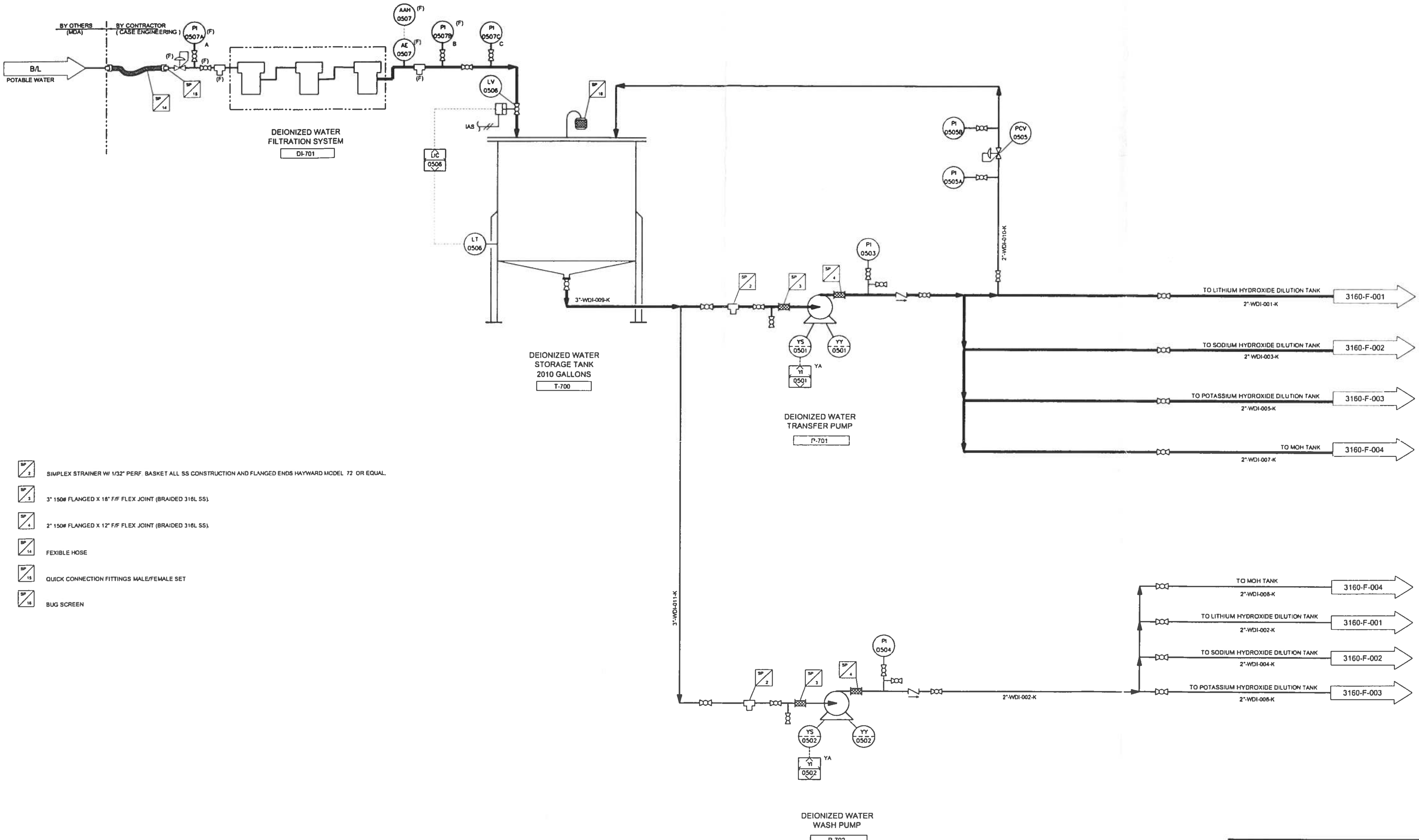


SP 2 — SIMPLEX STRAINER W/ 1/32" PERF. BASKET ALL SS CONSTRUCTION AND FLANGED ENDS HAYWARD MODEL 72 OR EQUAL.

SP 3 — 3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).

SP 4 — 2" 150# FLANGED X 12" F/F FLEX JOINT (BRAIDED 316L SS).

SP 14 — FEXIBLE HOSE

SP 15 — QUICK CONNECTION FITTINGS MALE/FEMALE SET

SP 16 — BUG SCREEN

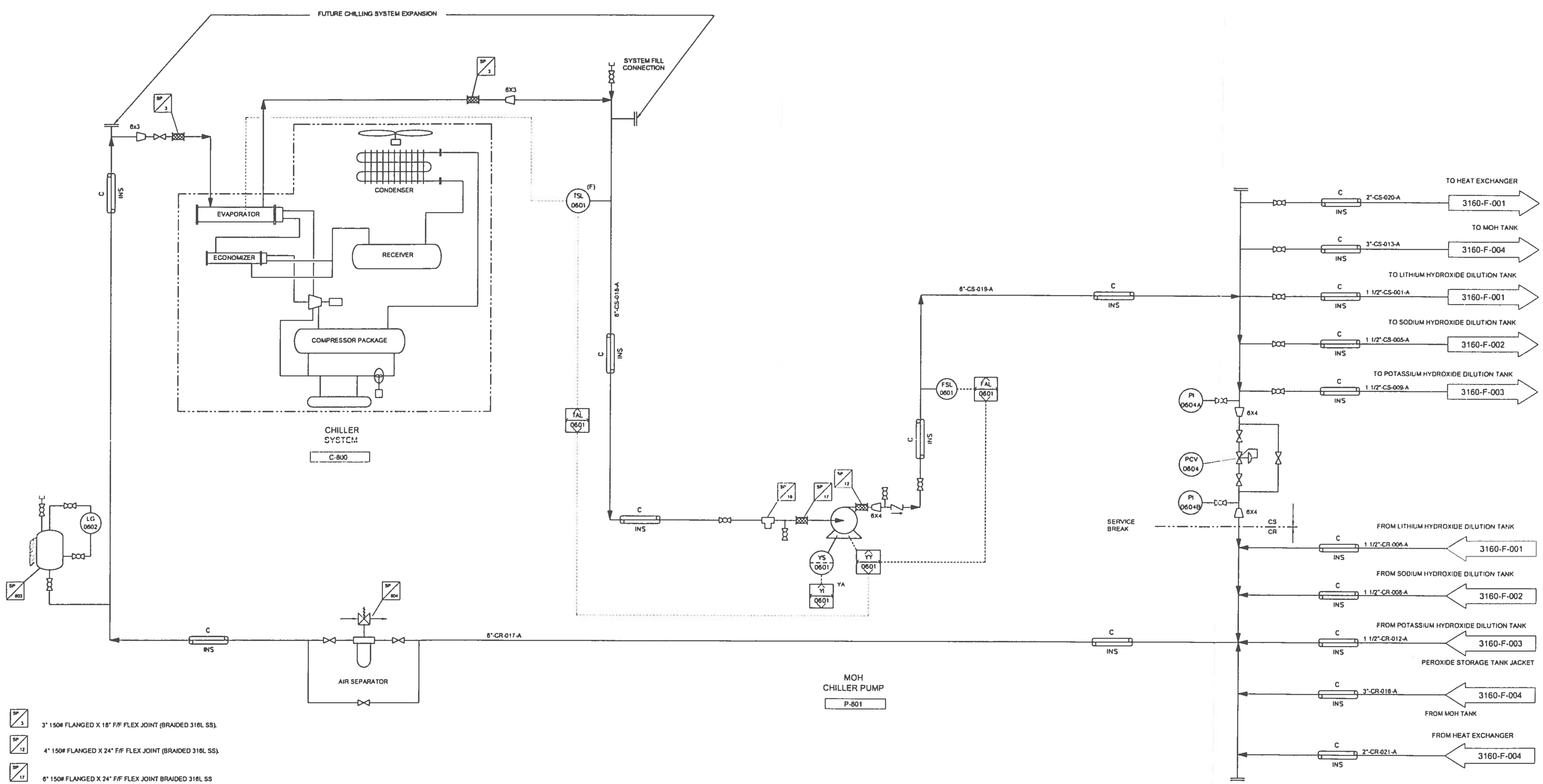
CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR-DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
DEIONIZED WATER MODULE

DRAWN BY	RMF	26AUG03	DSGN. BY	. .
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-F-005	REV. Po
RMF •3160F005 •03-25-04 @ 10:56				

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

REFERENCE DRAWINGS



SP 3 — 3" 150# FLANGED X 18" F/F FLEX JOINT (BRAIDED 316L SS).

SP 12 — 4" 150# FLANGED X 24" F/F FLEX JOINT (BRAIDED 316L SS).

SP 17 — 6" 150# FLANGED X 24" F/F FLEX JOINT BRAIDED 316L SS

SP 18 — 6" SIMPLEX STRAINER W/ 1/32" PERF. BASKET ALL SS CONSTRUCTION 150# FLGD. ENDS HAYWARD MODEL NO. 72 OR EQ.

SP 803 — CHILLER EXPANSION TANK

SP 804 — AIR SEPARATOR

REFERENCE DRAWINGS

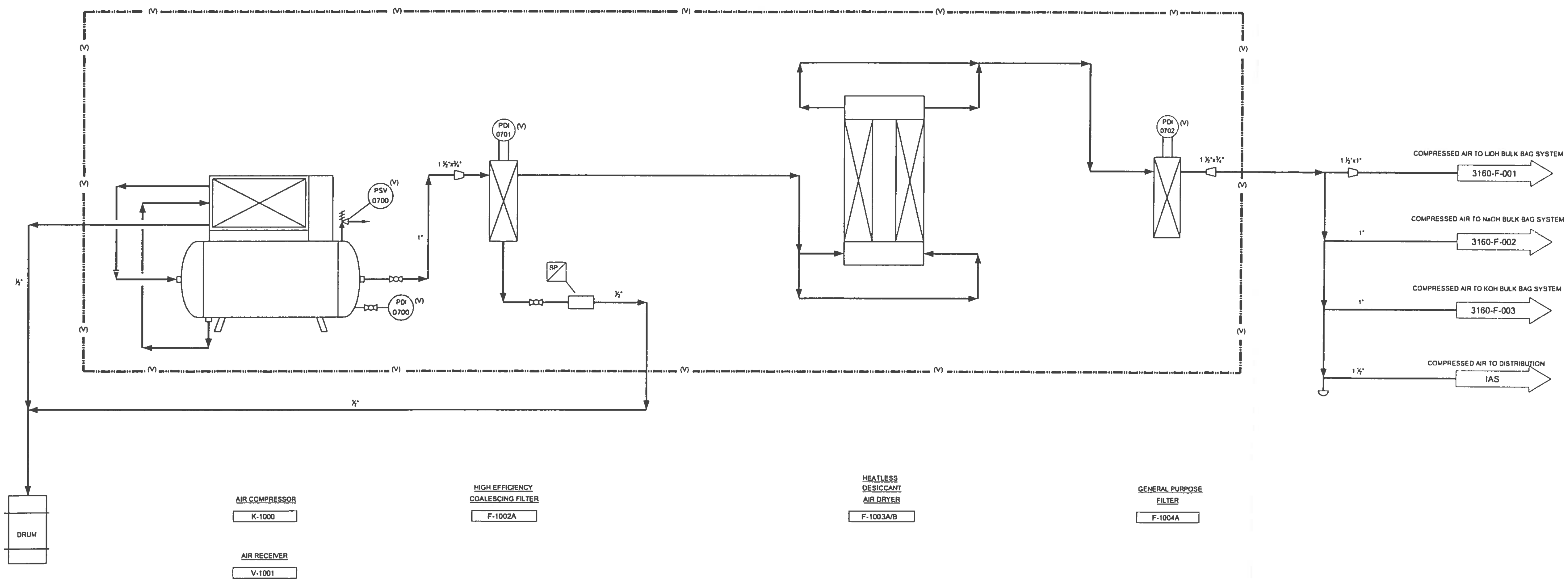
NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
CHILLER MODULE

DRAWN BY	RMF	26AUG03	DSGN. BY	.
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
CLIENT APPVL	.	.	DRAWING NO. 3160-F-006	REV. Po

RMF •3160F006 •03-25-04 @ 11:00



NOTE

THE "A/B" DESIGNATION DENOTES THAT THERE ARE TWO AIR COMPRESSOR SYSTEMS

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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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Po	PRELIMINARY	JFS	20MAY02	A	CHANGED PER DESIGN REVIEW MEETING-MAY 14, 2002	Po	20MAY02

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENCE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
PIPING AND INSTRUMENTATION DIAGRAM
PLANT AIR SYSTEM

DRAWN BY	DMN	3-21-02	DSGN. BY	. .
CHECKED BY	.	.	DWG. SCALE	FULL SIZE
APPROVED BY	.	.	PLOT SCALE	1 = 1
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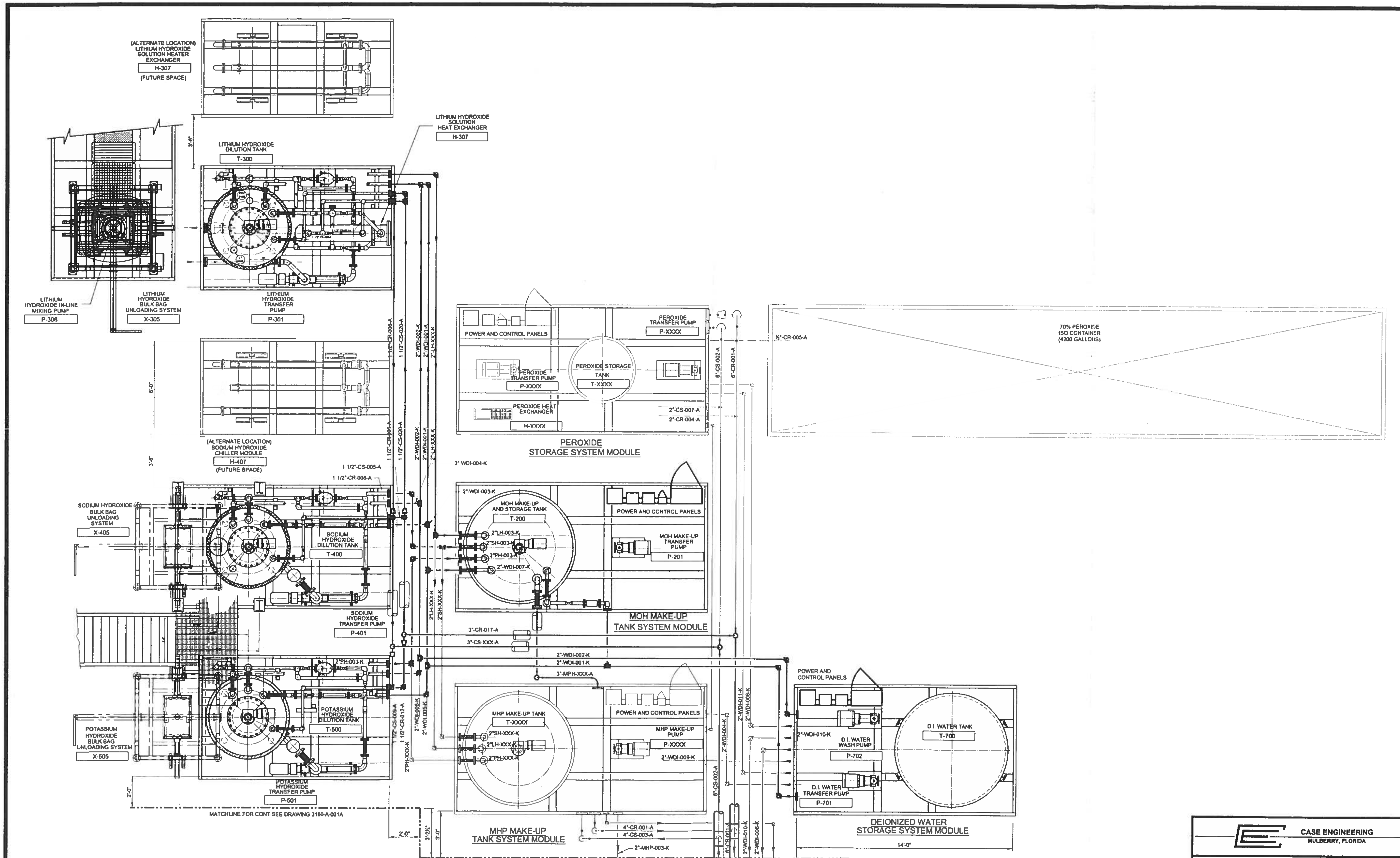
SECTION

6



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NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
				A	ISSUED FOR COMMENTS	Po	11-14-03

CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
OVERALL MODULE ARRANGEMENT
SHEET 1 OF 2

DRAWN BY	RMF	10MAR03	DSGN. BY	
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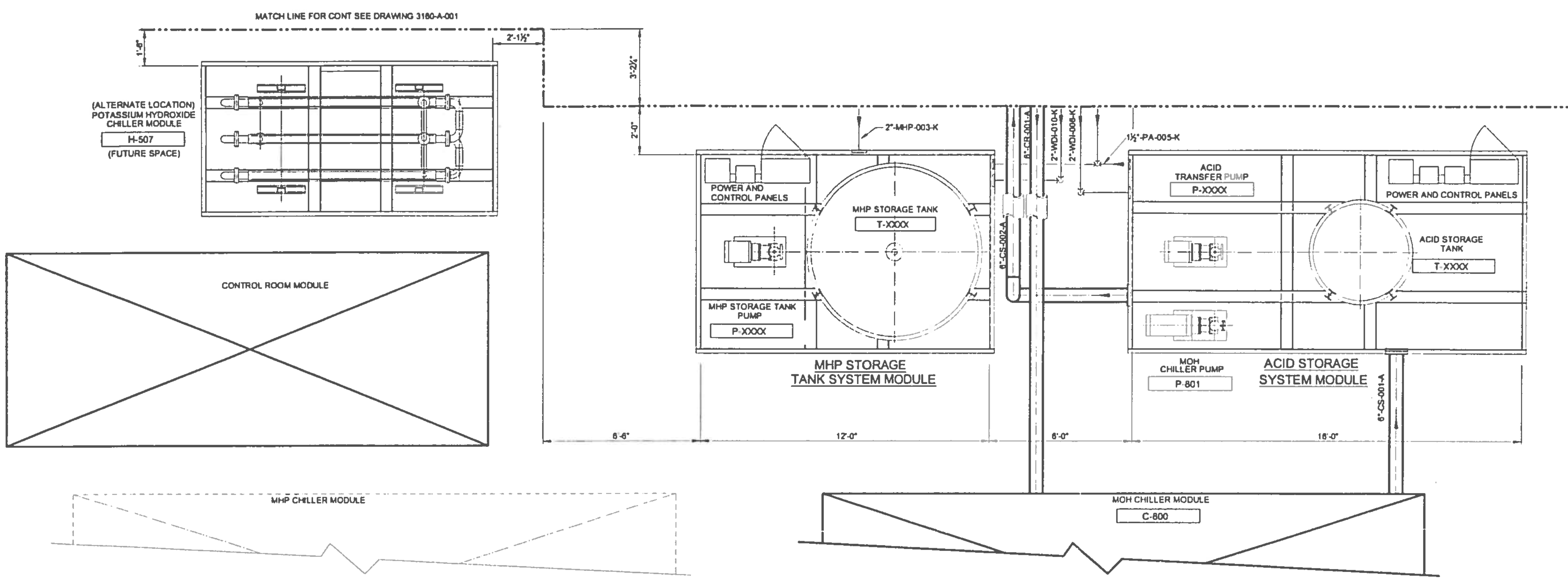
APPROVED BY			PLOT SCALE	1 = 32
CLIENT APPVL			DRAWING NO. 3160-A-001	REV Po



CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
OVERALL MODULE ARRANGEMENT
SHEET 2 OF 2

DRAWN BY	RMF	10MAR03	DSGN. BY	.	.
CHECKED BY	.	.	DWG. SCALE	3/16" = 1'-0"	
APPROVED BY	.	.	PLOT SCALE	1 = 32	
CLIENT APPVL	.	.	DRAWING NO. 3160-A-001A		REV. Po

RMF •3106A101 •03-25-04 @ 08:29

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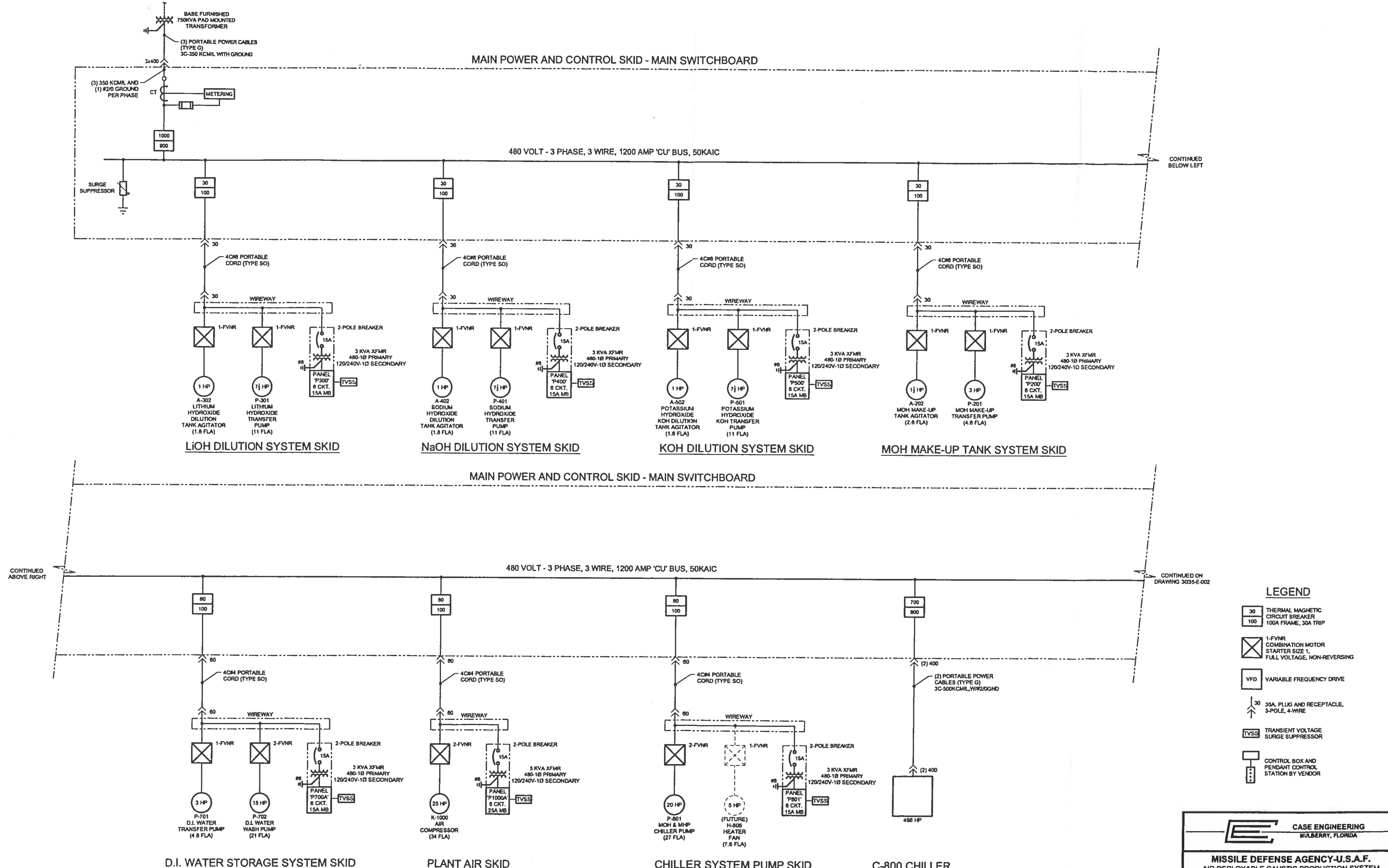
SECTION

7



CASE ENGINEERING
MULBERRY, FLORIDA

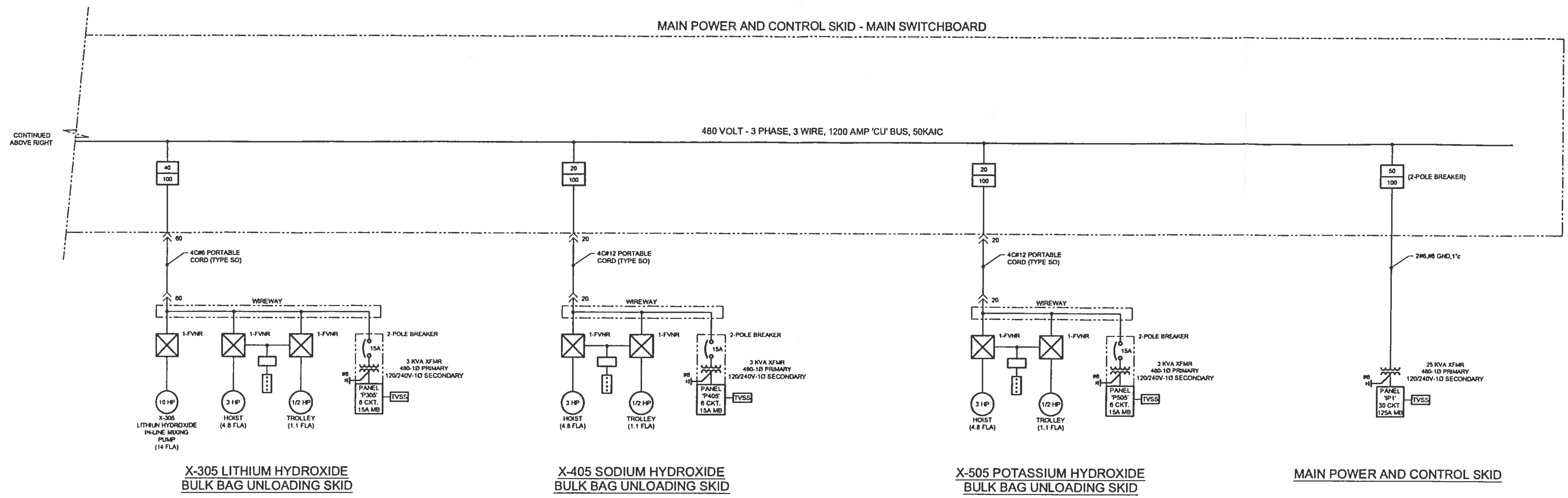
MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM

ELECTRICAL SINGLE LINE DIAGRAM

DRAWN BY	MF	13JAN04	DSGN. BY	SFH	13JAN04
CHECKED BY	.	.	DWG. SCALE	NONE	
APPROVED BY	.	.	PLOT SCALE	1 = 1	
CLIENT APPVL	.	.	DRAWING NO. 3160-E-001		REV. P0

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
				A	ISSUE FOR COMMENTS	P0	15JAN04

REFERENCE DRAWINGS



CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM

ELECTRICAL SINGLE LINE DIAGRAM

DRAWN BY	MF	13JAN04	DSGN. BY	SFH	13JAN04
CHECKED BY	.	.	DWG. SCALE	NONE	
APPROVED BY	.	.	PLOT SCALE	1 = 1	
CLIENT APPVL	.	.	DRAWING NO.		REV.

A | ISSUE FOR COMMENTS | P0 | 15JAN04

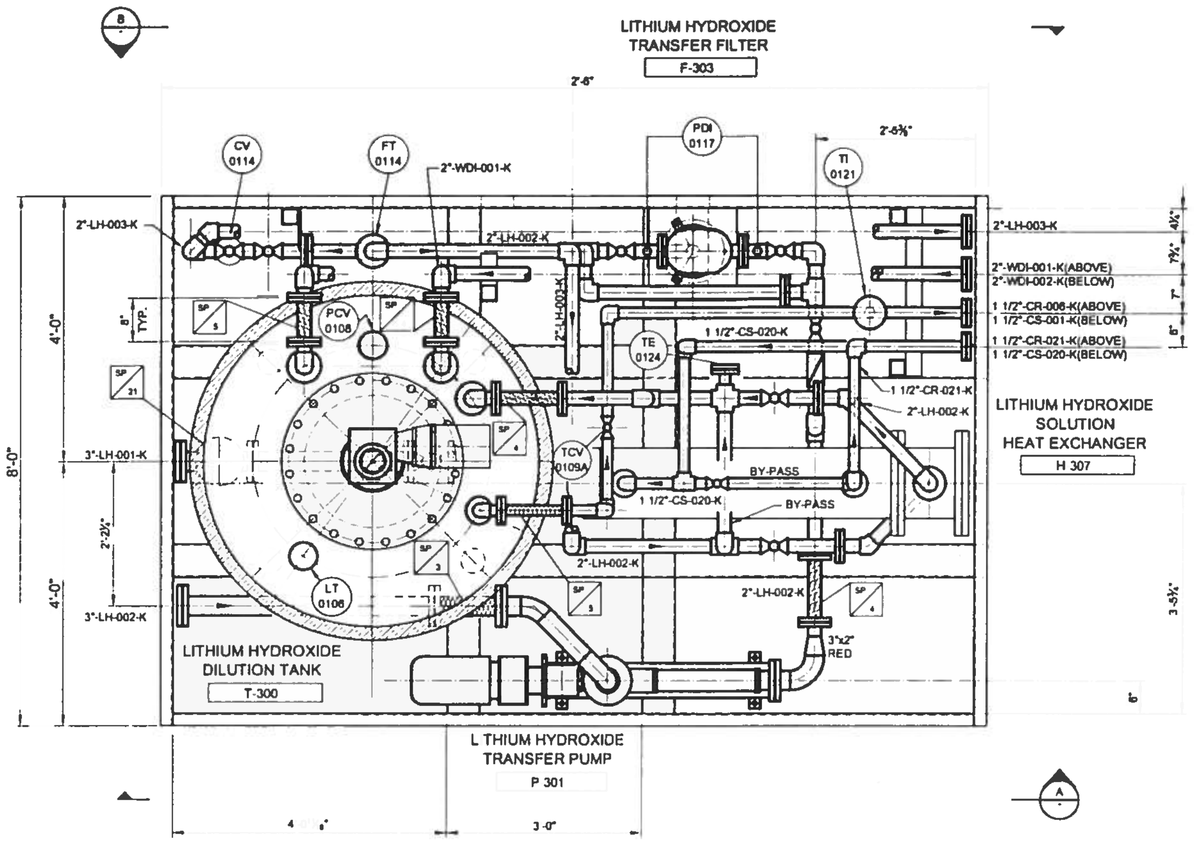
REFERENCE DRAWINGS

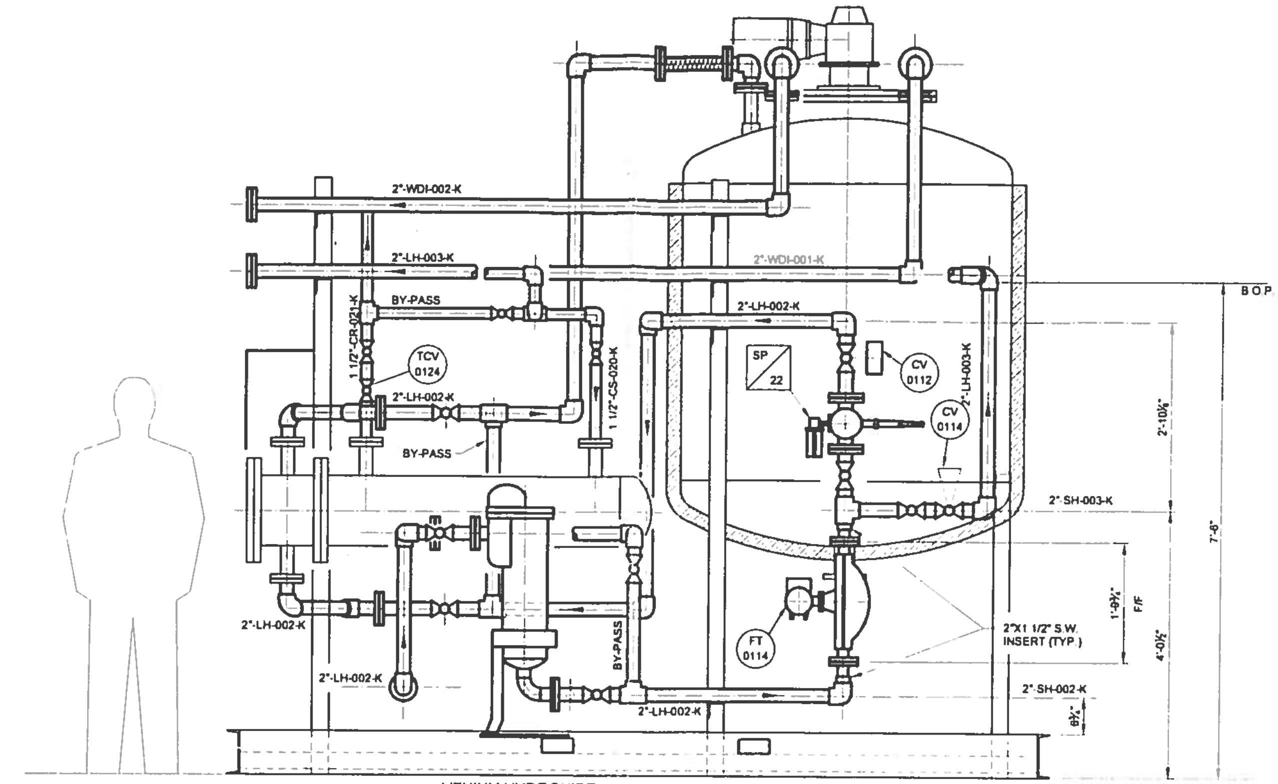
REVISION

DRAWING HISTORY

SECTION

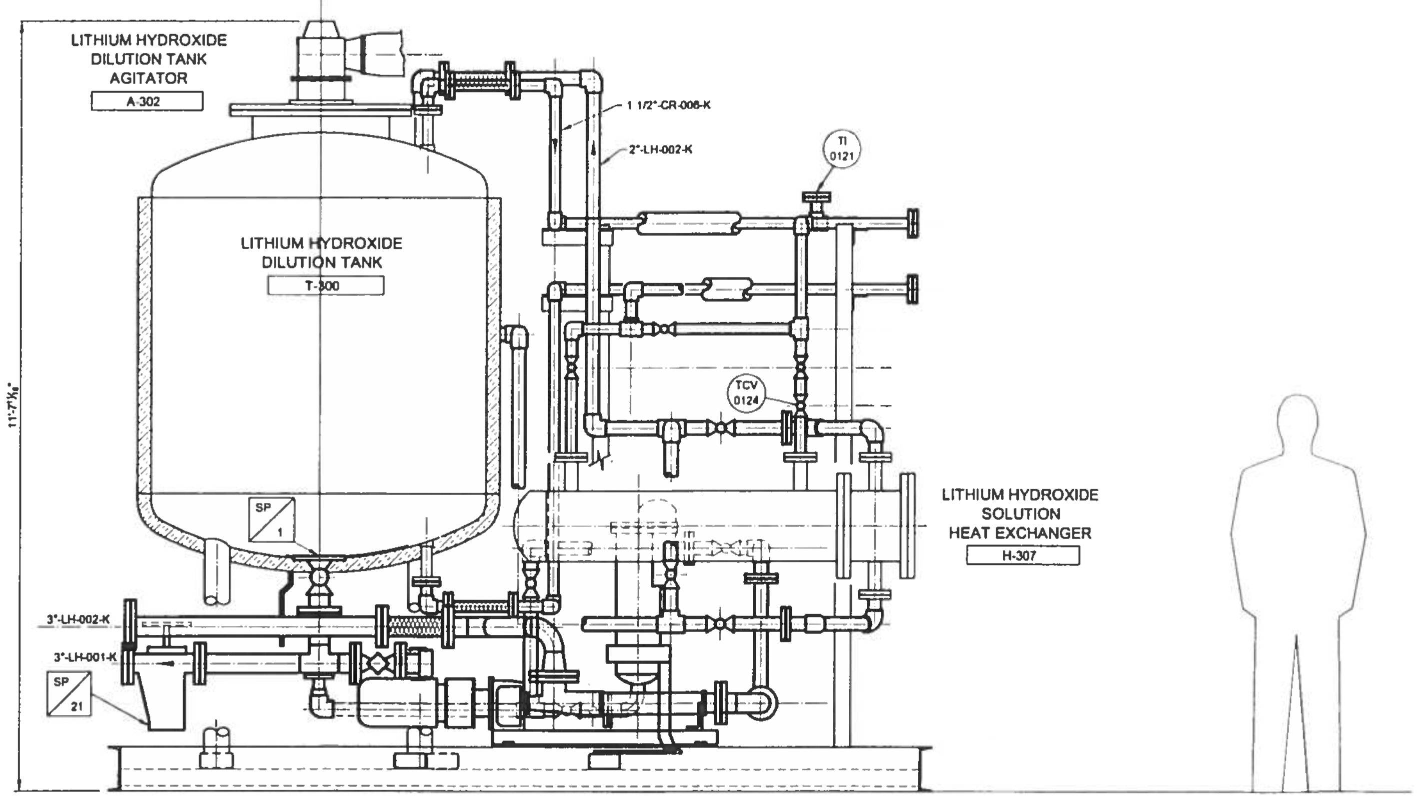
8





LITHIUM HYDROXIDE
TRANSFER FILTER
F-303

B SECTION
3/4" =1'-0"



LITHIUM HYDROXIDE
TRANSFER PUMP
P-301

A SECTION
3/4" =1'-0"

3160-F-001	P & I D - LITHIUM HYDROXIDE DILUTION
3160-V-001	T-400 LITHIUM HYDROXIDE DILUTION TANK
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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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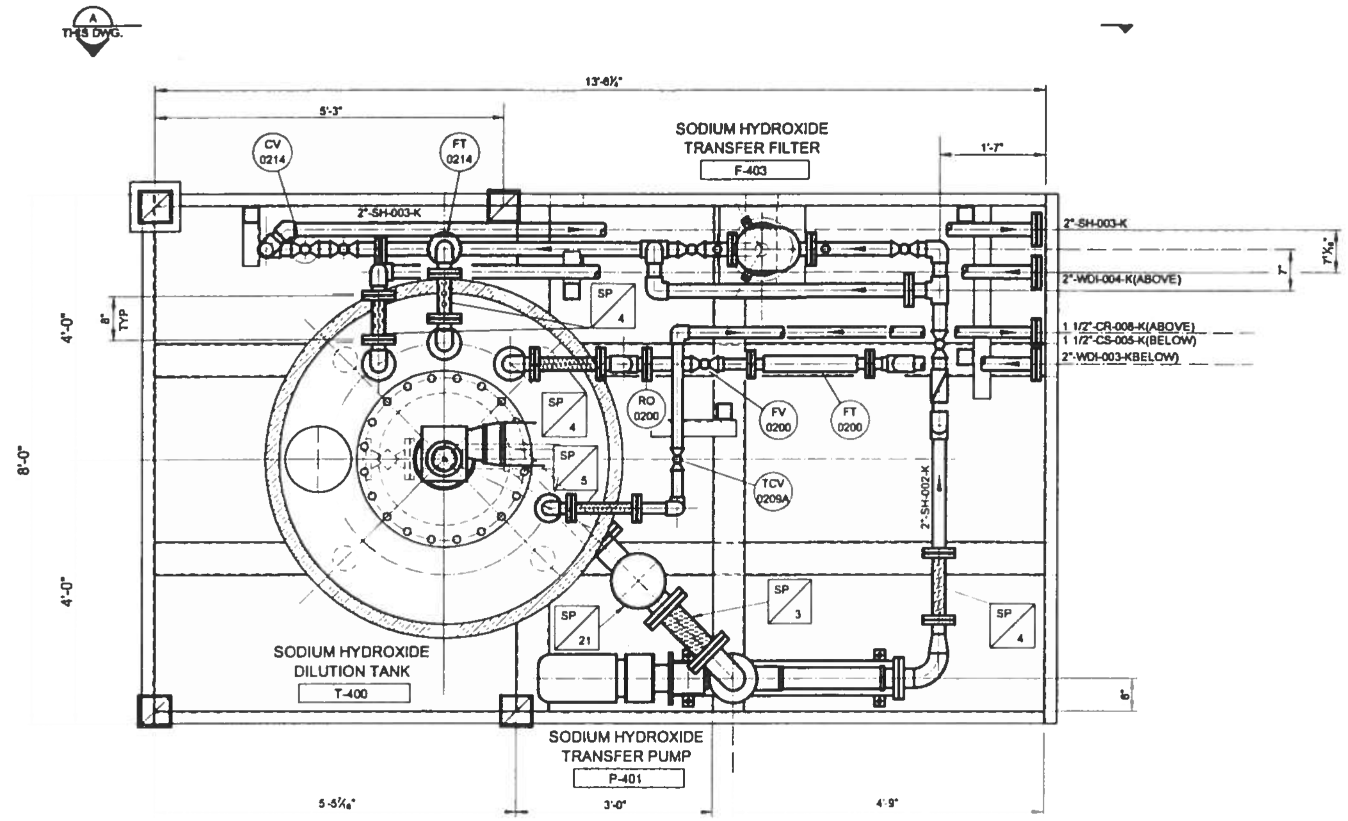
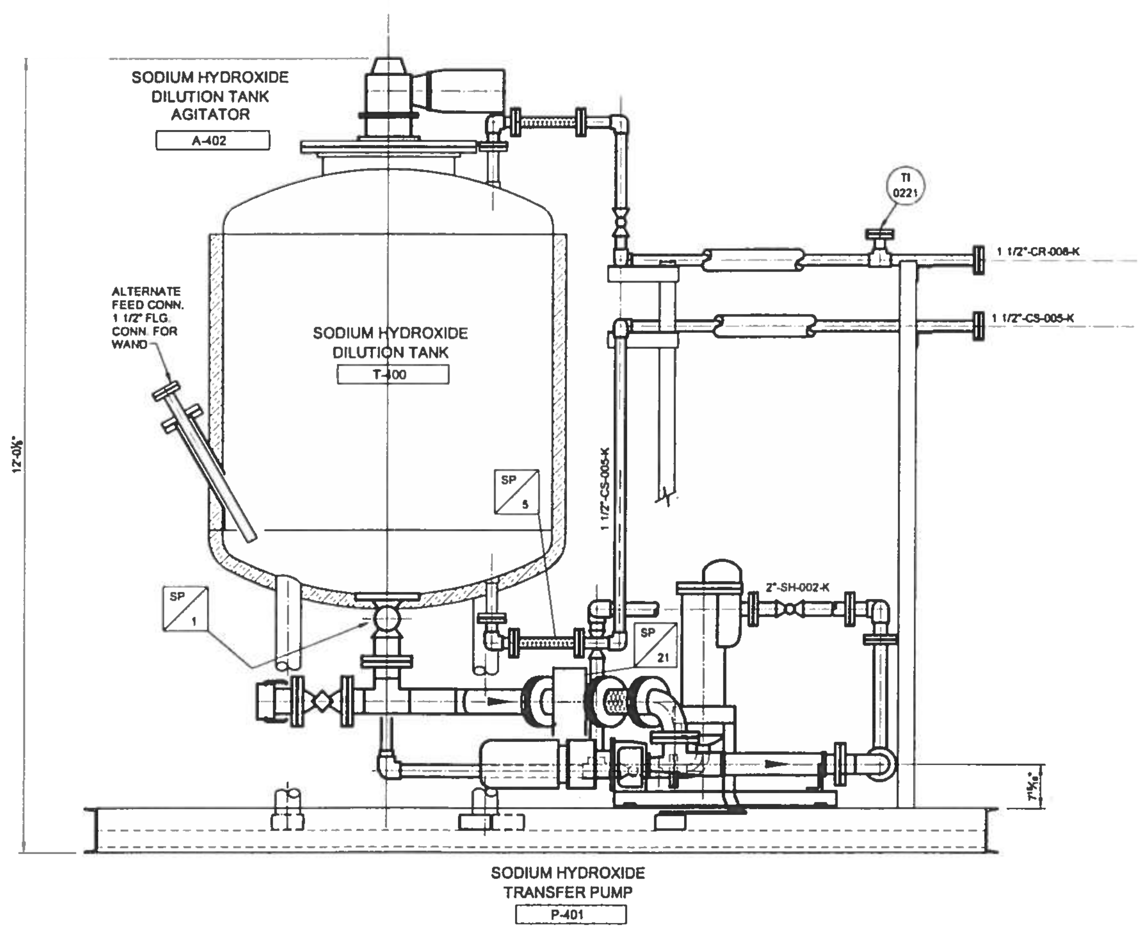
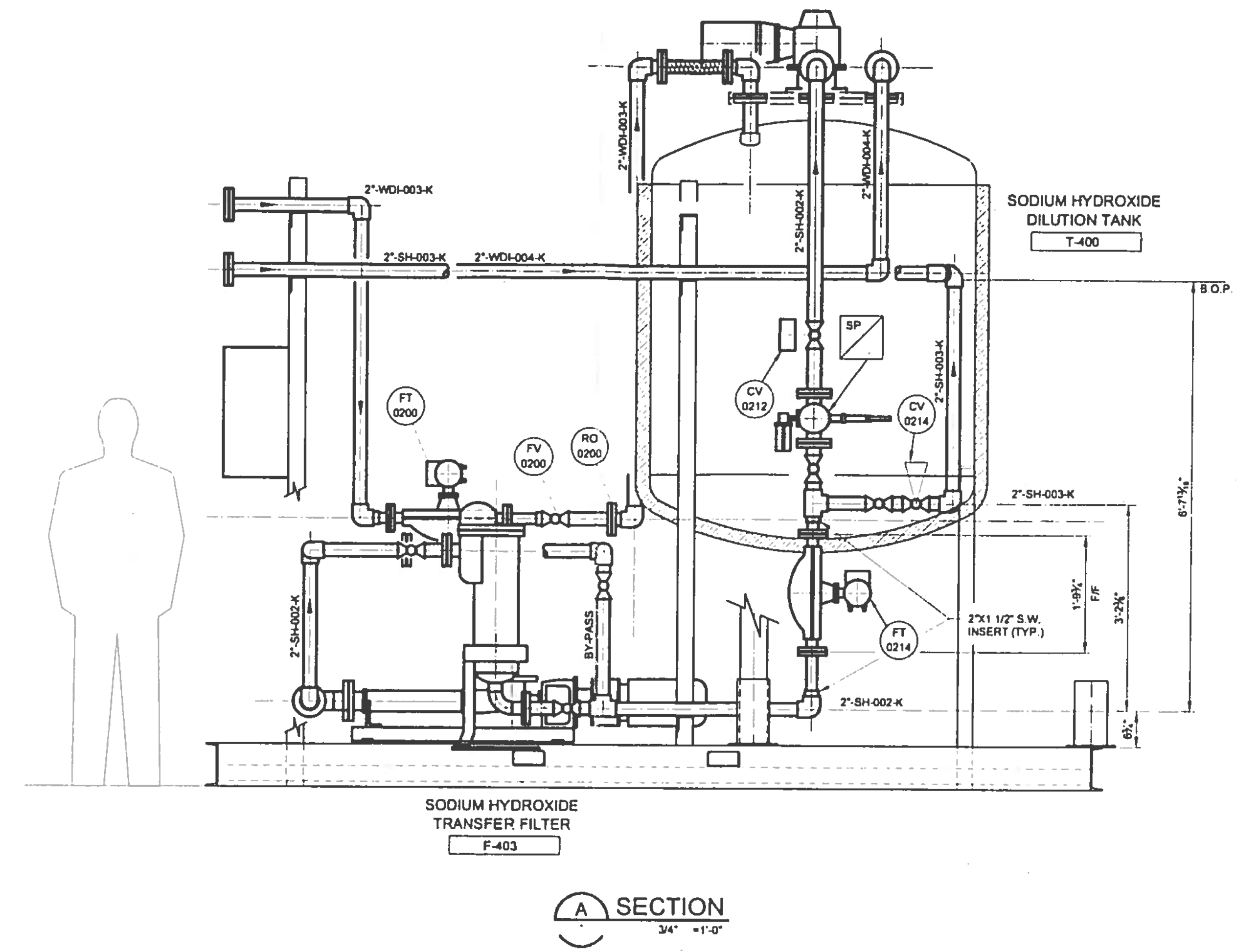
CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
LITHIUM HYDROXIDE DILUTION SYSTEM MODULE
PIPING

DRAWN BY	MLH	15MAY02	DSGN. BY	. .
CHECKED BY	.	.	DWG. SCALE	3/4" = 1'-0"
APPROVED BY	.	.	PLOT SCALE	1 = 16
CLIENT APPVL	.	.	DRAWING NO. 3160-P-001	REV. Po
RMF •3160P001A •03-25-04 @ 09:05				







3036-F-002	P & I D - SODIUM HYDROXIDE DILUTION
3036-V-002	T-400 SODIUM HYDROXIDE DILUTION TANK
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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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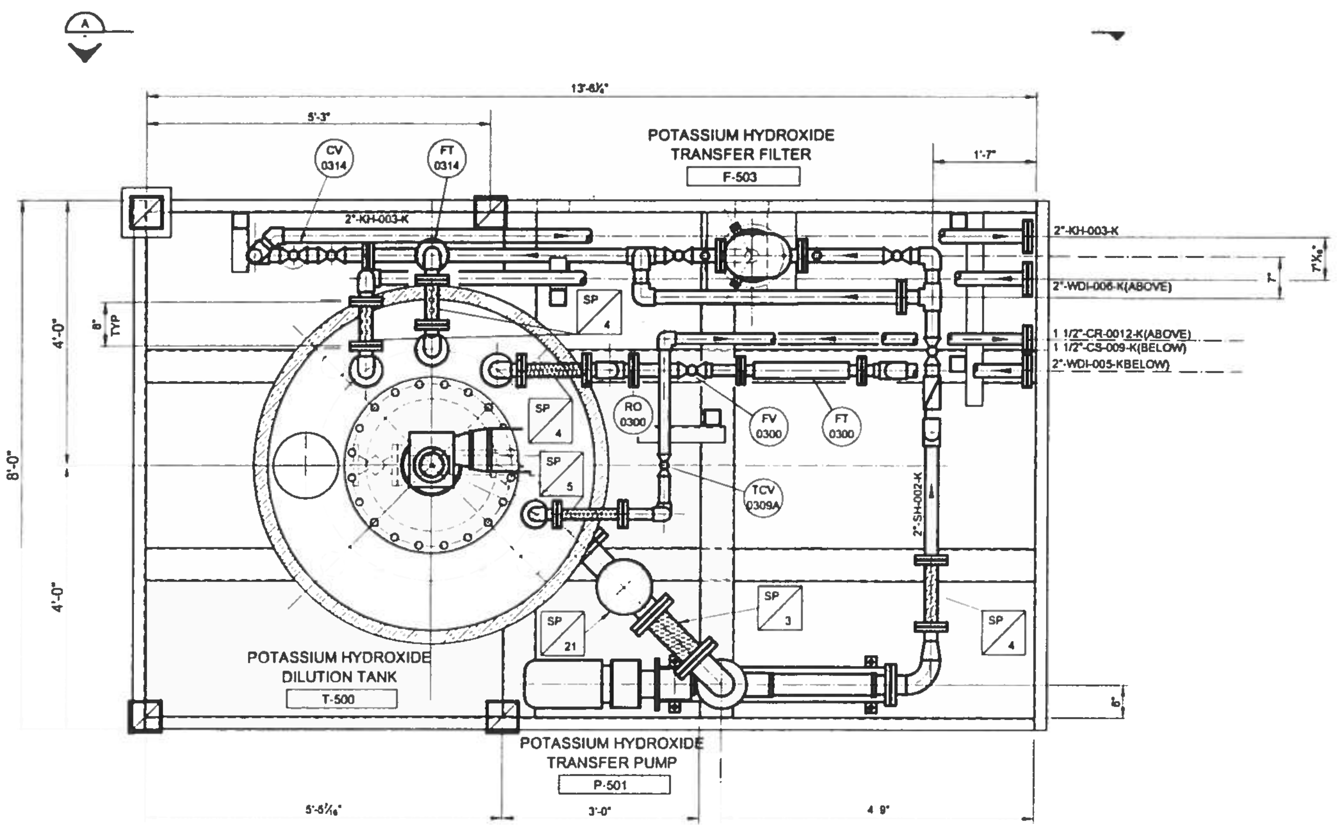
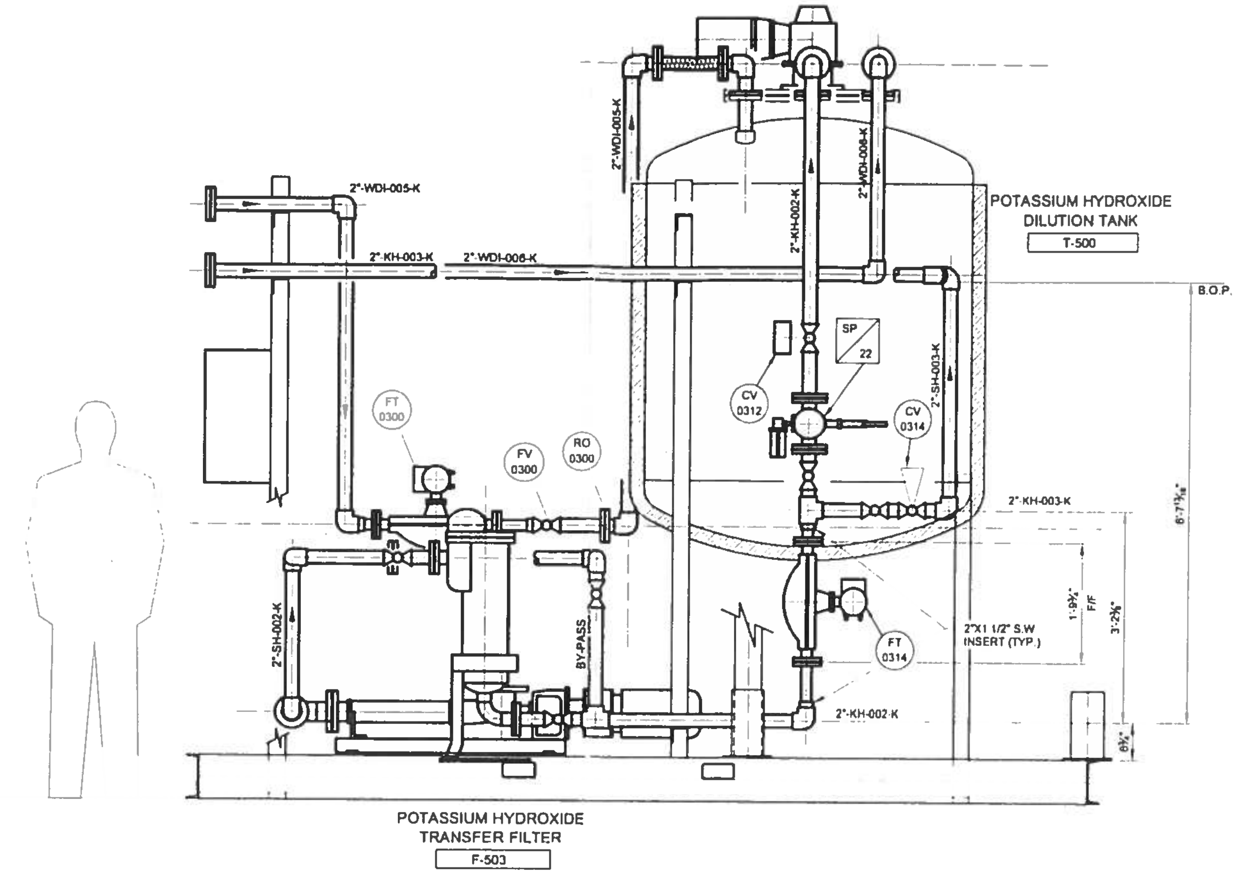
CASE ENGINEERING
MULBERRY, FLORIDA

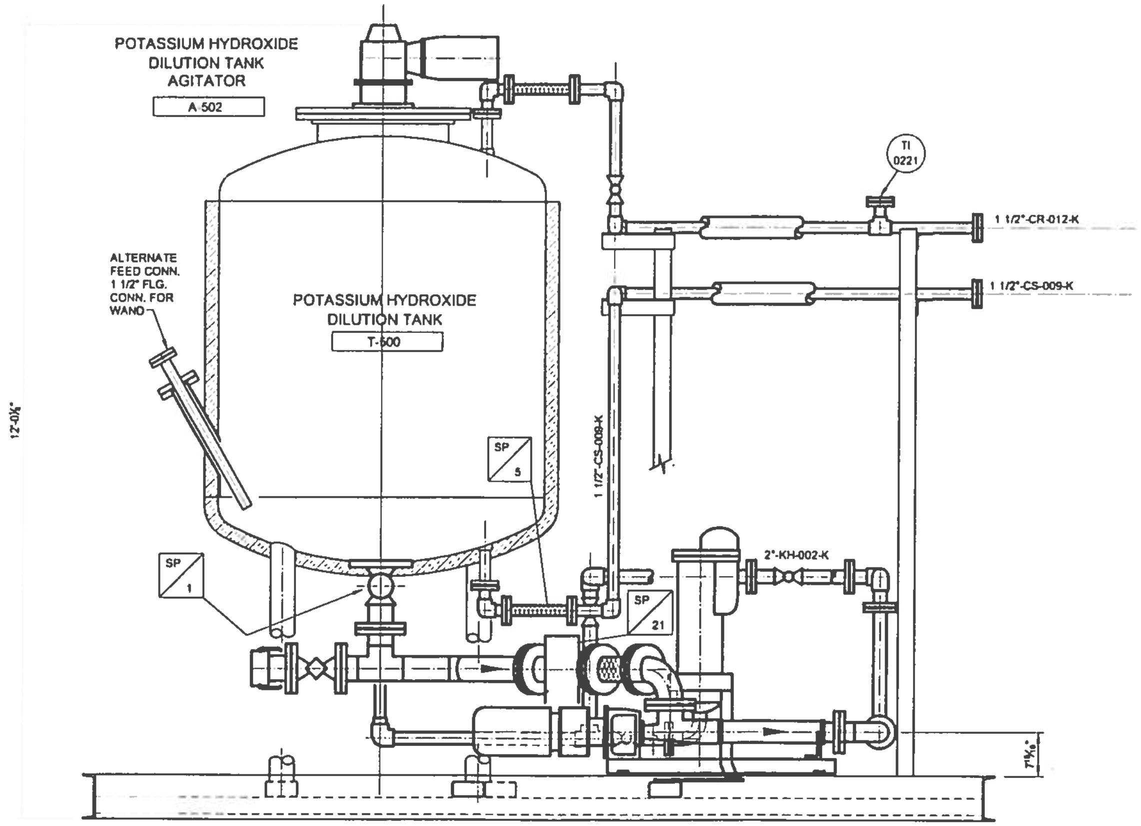
ADVANCED RESEARCH ASSOC.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
SODIUM HYDROXIDE DILUTION SYSTEM MODULE
PIPING

DRAWN BY	MLH	15MAY02	DSGN. BY	. .
CHECKED BY	.	.	DWG. SCALE	¾" = 1'-0"
APPROVED BY	.	.	PLOT SCALE	1 = 16
CLIENT APPVL	.	.	DRAWING NO. 3160-P-002	REV Po
RMF =3160P002 =03-25-04 @ 09:30				





A SECTION
3/4" = 1'-0"



POTASSIUM HYDROXIDE
TRANSFER PUMP
P-501

3035-F-002	P & I D - SODIUM HYDROXIDE DILUTION
3035-V-002	T-400 SODIUM HYDROXIDE DILUTION TANK
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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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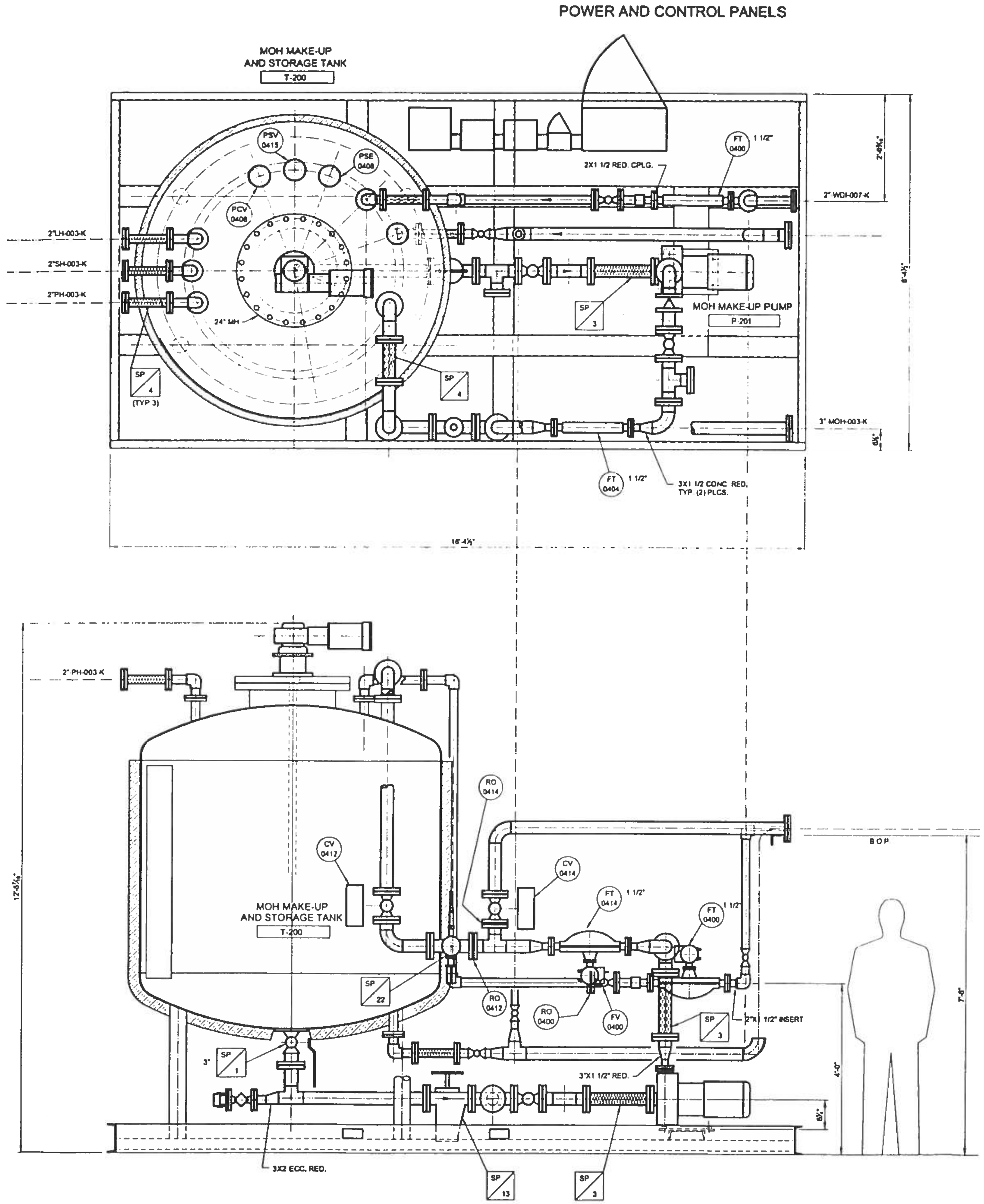
CASE ENGINEERING
MULBERRY, FLORIDA

ADVANCED RESEARCH ASSOC.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
POTASSIUM HYDROXIDE DILUTION SYSTEM MODULE
PIPING

DRAWN BY	MLH	15MAY02	DSGN. BY	.
CHECKED BY	.	.	DWG. SCALE	¾" = 1'-0"
APPROVED BY	.	.	PLOT SCALE	1 = 16
CLIENT APPVL	.	.	DRAWING NO. 3160-P-003	REV. Po

RMF +3160P003 +03-26-04 @ 07:50



3160-F-001	P & I D - LITHIUM HYDROXIDE DILUTION
3160-V-001	T-400 LITHIUM HYDROXIDE DILUTION TANK
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REFERENCE DRAWINGS	

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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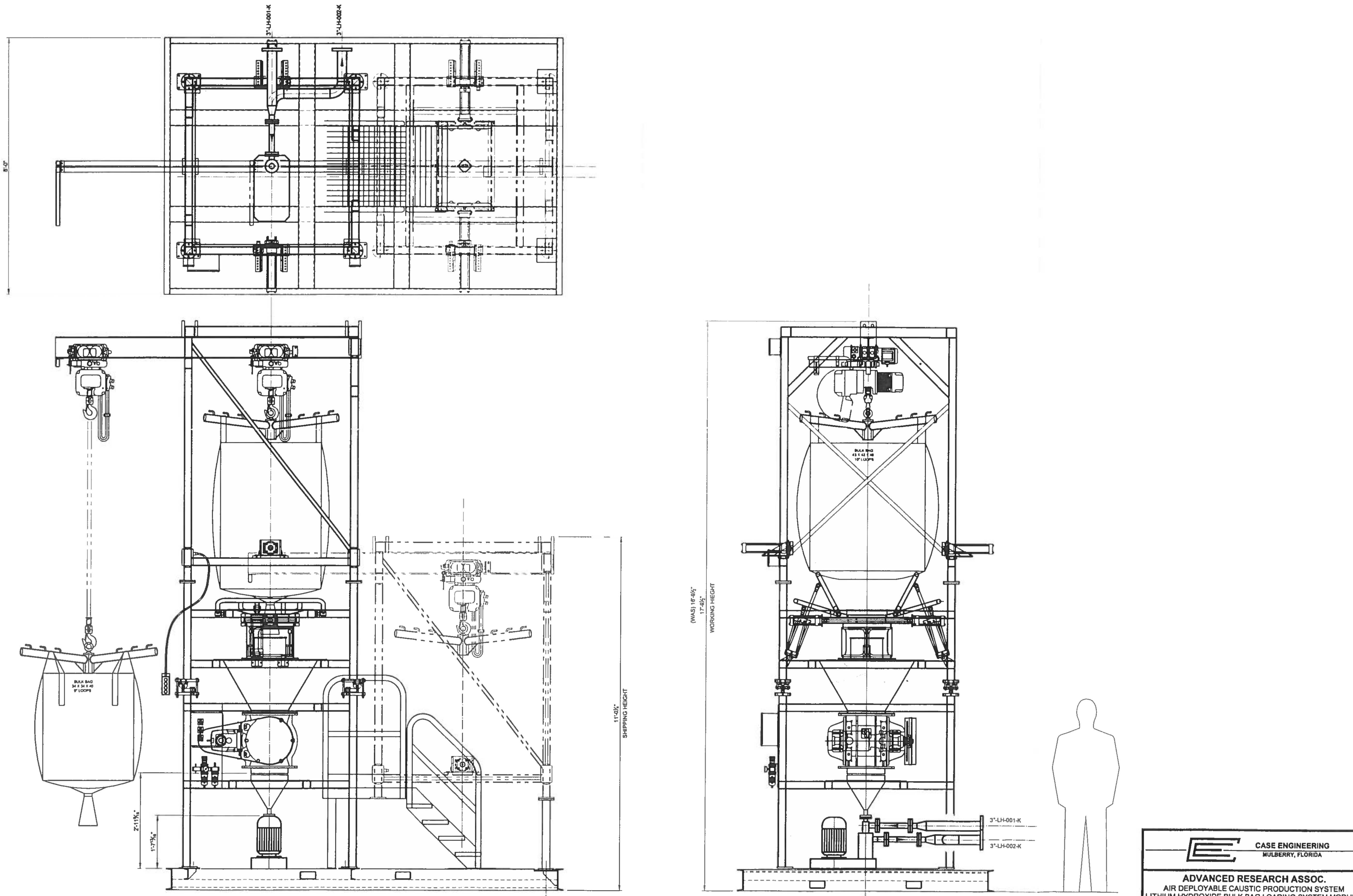
CASE ENGINEERING
MULBERRY, FLORIDA

MISSILE DEFENSE AGENCY-U.S.A.F.
AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
MOH MAKE-UP TANK SYSTEM MODULE
PIPING

DRAWN BY	MLH	15MAY02	DSGN. BY	. .
CHECKED BY	.	.	DWG. SCALE	¼" = 1'-0"
APPROVED BY	.	.	PLOT SCALE	1 = 16
CLIENT APPVL	.	.	DRAWING NO. 3160-P-004	REV. Po



3035-F-002	P & I D - SODIUM HYDROXIDE DILUTION
3035-V-002	T-400 SODIUM HYDROXIDE DILUTION TANK
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REFERENCE DRAWINGS

NO.	REVISION	BY	DATE	ISSUE	DRAWING HISTORY	REV.	DATE
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CASE ENGINEERING
MULBERRY, FLORIDA

ADVANCED RESEARCH ASSOC.

AIR DEPLOYABLE CAUSTIC PRODUCTION SYSTEM
LITHIUM HYDROXIDE BULK BAG LOADING SYSTEM MODULE
PIPING

DRAWN BY	MLH	15MAY02	DSGN. BY	.	.
CHECKED BY	.	.	DWG. SCALE	¾" = 1'-0"	
APPROVED BY	.	.	PLOT SCALE	1 = 16	
CLIENT APPVL	.	.	DRAWING NO.		REV.
G_E +3160P005	+01-07-04 @ 13:15		3160-P-005		Po