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SUBJECT: REED Besler Boiler High Pressure Steam System and Thermal Cycling Facility - Summary Report

TO: I. Spiewak

FROM: P. P. Holz

ABSTRACT

A high pressure boiler has been installed in Building 9204-1. This Besler boiler is capable of producing from 150 to 2000 psi saturated steam at steaming rates up to 5000 lbs/hr. The boiler is part of a water-steam circuit which also includes two spray water pumps, a steam pressure control valve, a high pressure trapping station, and a low pressure deaerated feedwater system.

The new boiler system is piped and instrumented to serve as a thermal cycling facility (Fig. 2). Shakedown test thermal cycles to requirements set forth in HRT Specification 1113a have been conducted using the existing Dump Test Autoclave as a test piece. Fourty-four cycles have been run through mid February, 1958. The boiler has been operated a total of 142 hours. Cycles are run completely automatically. Better than three-fourth of the cycles as run fall within the specification prescribed limits (Fig. 3).

This report is a condensed summary report. A more detailed report is also being issued under ORNL-CF- Memo 58-3-17.

NOTICE

This document contains information of a preliminary nature and was prepared primarily for internal use at the Oak Ridge National Laboratory. It is subject to revision or correction and therefore does not represent a final report.

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INTRODUCTION

Need for a steam boiler and system capable of delivering up to 5000 lb/hr at pressures up to 2000 psi as a central high pressure steam supply for REED in Building 9204-1 became progressively more important for the following reasons:

1. A facility to simplify the construction of test systems requiring high pressure steam. Individual small electric boilers usually involved considerable delay and expense in installation.

2. A thermal cycling facility to cycle large equipment to HRT specifications[1].

   a. Spare HRE-2 heat exchangers
   b. Titanium and titanium lined equipment. Pipes; heat exchangers
   c. Experimental and development reactor type equipment in general, of various metals. Pressure vessels, pipe, flanges, valves, etc.
   d. HRE-3 components

The purpose of the thermal cycling test is to uncover defects in fabrication, materials, and design that are not necessarily detected by routine inspection, and hydrostatic and helium leak tests.

Availability of a thermal cycling facility within the division eliminates high cumulative costs to different commercial reactor component fabricators for proper cycling tests.

3. A "heat exchanger test loop" to

   a. Investigate the performance with respect to time, and life of small steam generators modeled after advanced designs for homogeneous reactors.
   b. Study the behavior of UO_2SO_4 solutions when cycled between 250°C and 300°C as in a homogeneous reactor. This may include operations under conditions which are phase-stable at 250°C, but unstable at 300°C.
   c. Study corrosion and film formation at temperature extremes of the loop.
   d. Study feedwater treatment and possible secondary scale buildup on tubes. This might be coordinated with controlled Cl and O_2 additions.
   e. Investigate slurry heat transfer and the effect of rapid temperature cycling on slurry properties.

4. A facility for generalized studies of high pressure steam boiler feedwater treatment.

5. A system for development of high pressure steam valves, traps, flanged joints and instrumentation with later reactor application.

To accomplish these objectives a flexible facility was built (Figs. 1 and 2). Generally speaking, the facility can be broken down into three phases:

1. The Besler boiler system
2. The Thermal Cycle system
3. The heat exchanger test loop.

The Besler boiler system with the thermal cycling facility are described in this report. Provisions have been incorporated in the present installation to include the following building services:

1. Saturated steam at up to 2000 psi.
2. High pressure water at up to 600°F.
3. De-aerated feedwater.
4. Trapping facilities for return of condensate to the boiler system.

PROCEDURE FOR THERMAL CYCLING

A procedure for thermal cycling is set forth in HRT Specifications HRT 1113a(1) and in ORNL-CF Memo 58-2-48.[3] This procedure was specifically prepared for the HRT replacement heat exchanger. It is anticipated, however, that future specifications for other equipment will generally follow similar time-temperature patterns.

Figure 3 is a graphic representation of an average specified cycle. The lower temperature limits for cycling are to fall between 370°F and 390°F; the high limits, between 570°F and 590°F. A ten minute hold period is shown at each limit, however, it is permissible to increase these periods up to twenty minutes. The graph also indicates limiting five minute increment (maximum and minimum) slopes for the heating and cooling portions of each cycle; conditions are extremes, and should not be exceeded.

A period of not over three hours is specified to bring the test piece from room temperature up to 380°F prior to the initial cycle. A total of twenty-five consecutive thermal cycles are required of which at least twenty cycles must fall within the limits noted.

DESCRIPTION OF BESLER SYSTEM INCLUDING THERMAL CYCLING FACILITY

The Besler system including the thermal cycling facility is a carbon steel piping system. The high pressure phase is designed and fabricated for 2000 psi saturated steam service, and was hydrostatically tested to 3000 psi. All material and workmanship are to applicable Carbide Y-12 plant specifications.

Figure 1 illustrates the system schematically in detail, while Figure 2 represents a summary schematic flowsheet. Main components are as follows:

1. Besler Boiler

The boiler purchased as a package unit includes a feedwater pump, a fuel pump, a blower, as well as control and safety devices. Both pumps furnish constant flow rates and automatic valving is employed to recycle the water and fuel. Boiler safety devices include excess temperature and pressure cutouts and a steam separator just ahead of the boiler safety valve. This separator assures excess moisture throughout all boiler tubes all the time. The water leg of the separator is drained by a level controlled valve to prevent flooding the steam system.

The boiler package unit also included a boiler pressure controller. For thermal cycling, this controller is bypassed. Instead, predetermined controlled pneumatic evaporation output rate signals are provided as described later. It is planned, however, to employ boiler pressure control for heat exchanger test loop operation.

Major specifications of the boiler are as follows:

Capacity - Maximum, 2 section operation, 5000 lb/hr.

- Minimum, 1 section operation, 500 lb/hr.

Working Pressure - Maximum, 2000 psi (saturated steam)

- Minimum, 150 psi (saturated steam)

Fuel - No. 2 grade fuel oil

Motors, all 220/440 V, 60 cycles

Feedwater pump - triplex	- 25 HP
Blower	- 7 1/2 HP
Fuel oil	- 1/2 HP

Controls - 110 V, 60 cycle interlocks

Safety Devices - Safety valve 2200 psi

Low water cutout

High pressure and high temperature cutouts

Control power interlocks to ignition and burner fuel supply circuits

Flue - 18-in. x 24-in., with damper.

2. Spray Cooler

The spray cooler is a contact heat exchanger. Two positive displacement water pumps force water through a check valve to a preheat coil. The end section of the coil contains numerous small spray holes.

Each pump is capable of supplying up to 2 1/4 gallons of water per minute. Hence, a maximum 4 1/2 gallon spray capacity is available. The pump discharge header includes an automatically controlled relief valve bypass recycling stream to adjust water spray rates as required.

3. Test Piece

Presently, the test piece is the dump test autoclave. Steam enters at its top, leaves at the bottom. The control thermocouple is attached to the exit pipe. Future test pieces will be similarly connected. Test pieces of small size and heating surface area may be connected in series behind the existing autoclave.

4. Steam Water Separator - Control Valve and Trapping Station (Fig. 1)

Discharge from the test piece will vary from superheated steam to high quality, or "wet" steam during each cycle. The discharge steam is piped through a steam-water separator to properly strip excess water content before the steam is throttled through the control valve. Condensate, in turn, is sent to a high pressure trapping station.

A 1 1/2-in. Hammel Dahl control valve, actuated by a temperature-recorder-controller, is used to maintain proper system pressures for the required cycle temperatures. The valve is equipped with a positioner.

The trapping station consists of three parallel 1 1/2-in. Velan traps, each with individual bypass. All traps operate on an adjustable bimetallic plate mechanism, sensing the temperature differential between steam and condensate. Two traps will handle the system capacity, three are installed to permit continuous system operation while possible trap repairs are made.

5. Low Pressure Deaerator Supply Piping (Fig. 1)

Steam returns from the main control valve and the high pressure trapping station merge into an outdoor, uninsulated deaerator return pipe. This pipe is a 6-in. line with a 12-in. bottom section which accommodates the flashing mixture from the high pressure traps. The deaerator is located approximately sixty feet above the trapping station, hence condensate returns must be elevated. This is accomplished by providing a 4-in. x 6-in. Crosby angle relief valve to the steam portion of the 6-in. return line at the deaerator level. The relief valve intermittently seals off the low pressure system and thus forces condensate to flow via the bottom of the 12-in. "flashing" section through a low pressure trap and 1 1/2-in. line directly back into the deaerator.

6. Deaerator

A deaerator with an external vent condenser is located at the highest elevation of the low pressure system. This 15,000 lbs/hr capacity deaerator, built by the American Water Softener Company is of the spray-atomizing type. Oxygen content of the effluent feedwater is guaranteed at 5 ppm, although an average of 2 ppm was attained during operation.

7. Storage Tanks

A 5000 gallon feedwater storage tank is located directly below the deaerator. Another 5000 gallon tank, located on a pad in a curbed outside enclosure serves as a fuel reservoir for the boiler.

8. Control Instrumentation (Fig. 2)

Control instrumentation consists primarily of a temperature-recorder-controller. This instrument receives its signal from a thermocouple located at the test piece exit pipe. The signal enters the controller through an electro-pneumatic converter. The pneumatic receiver-recorder-controller is also arranged to vary with a set point introduced by a cam on a pneumatic time schedule programmer. The controller's pneumatic output signal is transmitted to the control valve which opens and closes as directed so as to match thermocouple and programmed cam temperatures. The boiler, meanwhile, can be set to operate at either constant evaporation rate, or at a predetermined varying rate. This variance is obtained by taking a pneumatic signal from the time programmer through a pneumatic computer which subtracts a fixed amount. In turn, this new pneumatic setting is fed to the boiler output air motor regulator.

Spray pump output is regulated by manually setting a recirculating bypass line control valve opening. A standard pneumatic recorder controller in turn receives an input signal from a pneumatic transmitting pump suction rotameter and regulates pump output to the spray chamber.

9. Miscellaneous Interconnections

The Besler steam system is interconnected with isolation valves to the building 250 psi steam system. This building supply is utilized for warmup and low temperature operations.

The deaerator supply system is also tied in with the building 125 psi steam service for boiler makeup water operation.

Both tie ins include steam pressure regulating stations.

DISCUSSION OF SHAKEDOWN - ANALYSIS OF RESULTS

Initial shakedown test thermal cycles on the autoclave setup produced inconclusive results. Troubles included improper thermocouple locations, incomplete insulation of couples and the test piece, lack of separation of water and steam in the high pressure separator, faulty main steam control valve positioner travel, sticking linkages in control instruments, and instrument standardization effects.

Cycling with constant boiler evaporation rates proved difficult. Low steaming rates permitted ease of operation in the low temperature portions of thermal cycles, however, insufficient boiler driving force prevented attainment of the high temperatures. Similarly, high steaming rates provided ideal conditions for the upper cycle limits, but despite maximum utilization of available spray cooling water capacity, prevented proper control at the lower cycle temperatures. Stepped boiler output control remedied the difficulties. Automatically computer controlled boiler evaporation output permitted excellent reproducibility of cycles.

Test cycles indicate that initial cycles always tend to overshoot the mean upper limit by about 3°C. Subsequent cycles, however, all tend to level out at the proper same upper setting. Conversely, a tendency exists at the lower limit where the levelling out of the finish of all cycles appears about 3°C above the starting cycle's low limit. This behavior is attributed to "stored heat" in the steel mass of the autoclave. The relatively short heating and cooling periods called for by the HRT cycling specifications do not allow sufficient time for uniform heat absorption or rejection of the various thicknesses of the test piece steel shell with its flanges, etc. A maximum temperature differential exists during the initial cycle. This difference decreases with subsequent cycles, and eventually becomes near constant. Snyder's Memo 58-2-48[3] presents the mathematical approach and calculations for temperature gradient relationship.

Early runs also demonstrated the importance of balanced, or equilibrium boiler and and system conditions at the outset of each cycling run. Care must be taken to shift carefully from the 250 psi building steam supply over to boiler steam. Sufficient time must then be allowed to permit the boiler to equalize before a thermal cycle run is made. During this waiting period, it is also important to standardize the time-temperature controller frequently before placing its standardization timing on the automatic 2 hr cycle.

Cycling runs confirm the boiler manufacturer's recommendation to clear the steam generator's firesides by soot blowing at eight hour intervals. It has been demonstrated that soot blowing can be conducted during the low temperature hold portions of cycles without exceeding temperature limits set forth in the governing HRT specifications.

A periodic boiler maintenance program and boiler feedwater ph and oxygen content control must be followed to maintain the steam generating source in best possible condition at all times.

CONCLUSIONS

The high pressure boiler installation in Building 9204-1 is ready to be used to thermal cycle any test equipment up to 300°C, with saturated steaming rates up to 5000 lbs/hr. It is possible to properly thermal cycle test equipment, maintain specified heating and cooling rates, attain reproducibility of consecutive cycles, and to cycle for extended time periods.

The use of sprayed cooling water introduced to the boiler exit steam during the cooling cycles assists in properly controlling temperature, particularly at the low end of each cycle.

Programmed boiler output varying directly with time-temperature cam signals should be employed for all thermal cycling operations.

The Besler system is also available for controlled pressure output operation. Only minor connecting piping alterations are required before the facility can be adapted for heat exchanger test loop heat source application. It should be pointed out that during the thermal cycling of an equipment item, normal building supply of high pressure Besler steam will be interrupted.

APPENDIX

The following Carbide drawings were issued for the construction of the Besler System:

Sketch D101	Besler System Preliminary General Floor Plan Layout	
Sketch D102	" " "	Plan View-Connecting Boiler Piping
Sketch D103	" " "	Plan View-Feedwater Tank and Spray Pump Piping
Sketch D104	" " "	Elevations-Bldg. 9204-1 East Wall Piping
Sketch D105	" " "	Elevations-Deaerator and Feed Water Tank
Sketch 490	Wall Sleeve Layout East Wall, Bldg. 9204-1	
Dwg. TD-E-3212	Besler System -Overall Plan View	
TD-D-3213	" "	Boiler Rotameter Layout
TD-D-3214	" "	Deaerator and Return Piping to Feedwater Storage Tank
TD-D-3215	" "	Steam Pressure Reducing Stations
TD-D-3216	" "	Elevations, Bldg. 9204-1 East Wall Piping
TD-D-3217	" "	Water Spray Pump Layout
TD-D-3218	" "	Trap Station Layout
TD-C-3243	" "	Details, Steam Water Mixing Chamber
TD-E-4879	" "	Instrument Flowsheet
E-HV-21965	" "	High Pressure Boiler, Stack and Breeching
E-S-21862	" "	Structural Base Plans and Details
D-P-21753	" "	Fuel Oil and Air Piping

REFERENCES

(1) HRT Specification HRT 1113a.

(2) P. P. Holz, "REED Besler Boiler High Pressure Steam System and Thermal Cycling Facility - Detailed Report," ORNL-CF- 58-3-17, March 4, 1958.

(3) D. L. Snyder, "Thermal Cycle Procedure and Analysis for the HRT Replacement Heat Exchanger," ORNL-CF-58-2-48, February 12, 1958.

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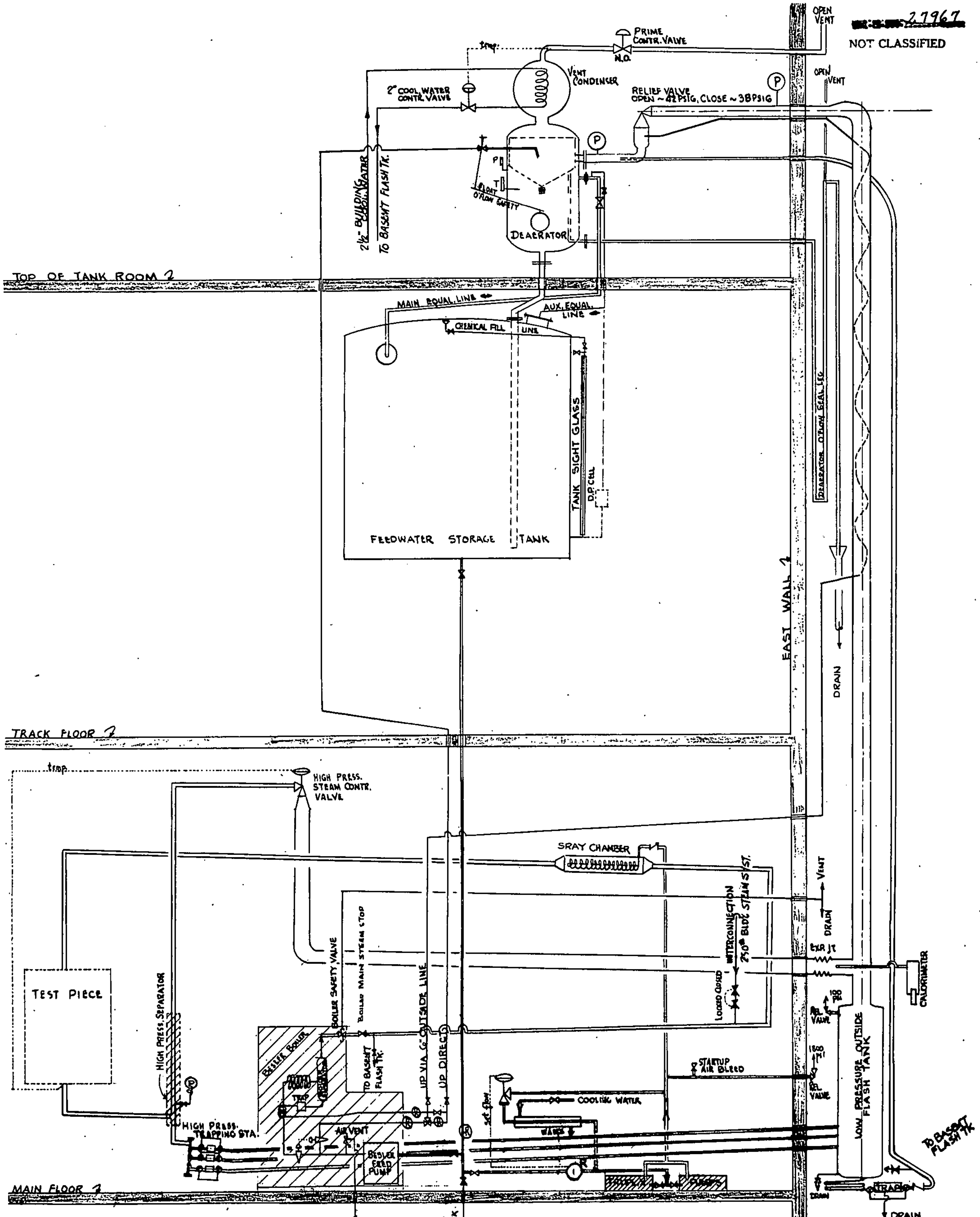

BUILDING 9204-1

BESLER BOILER FACILITY - THERMAL CYCLE SYSTEM

SCHEMATIC - NO SCALE

FIG. 1

ORNL-LR-DWG-27968

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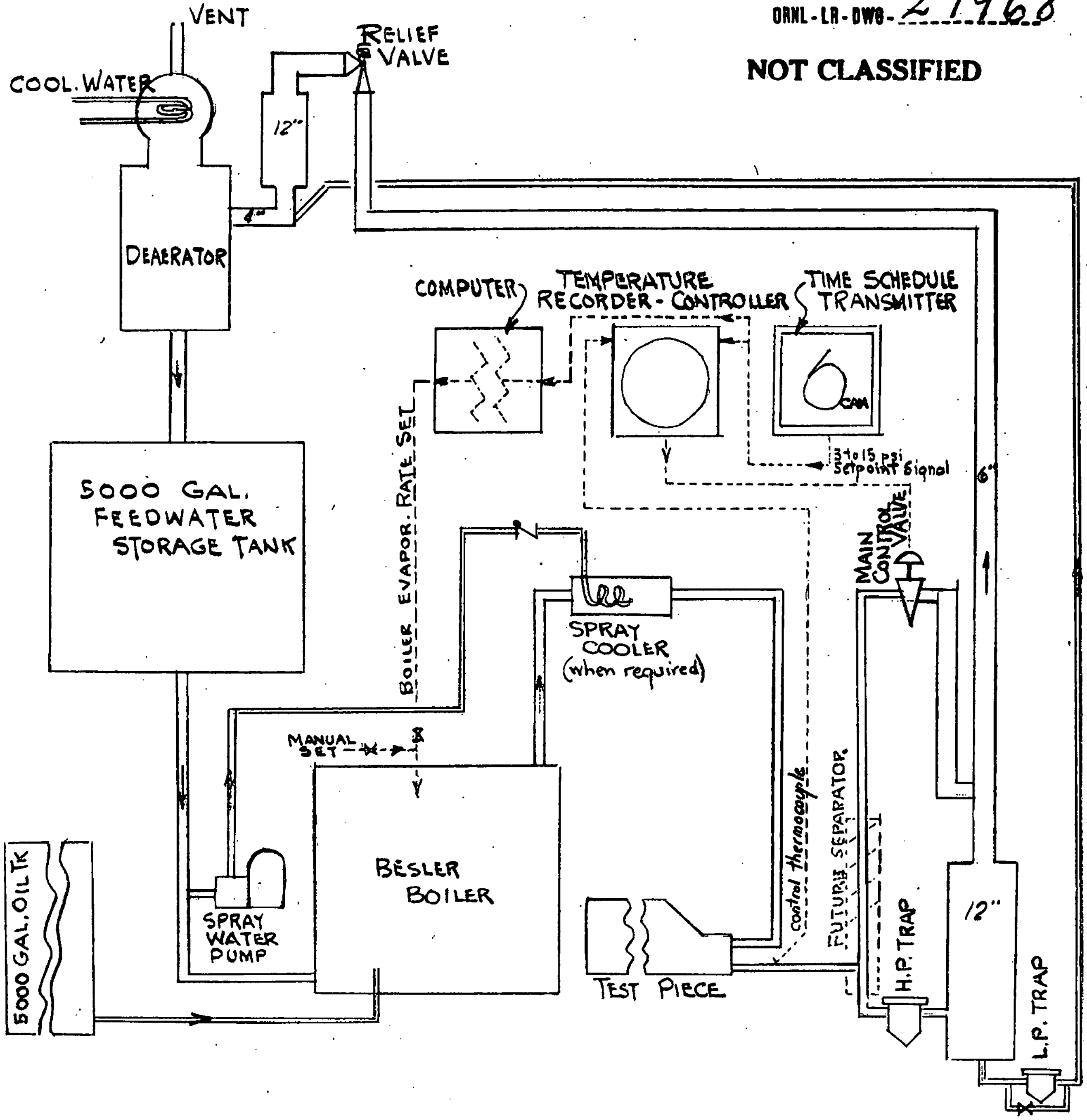
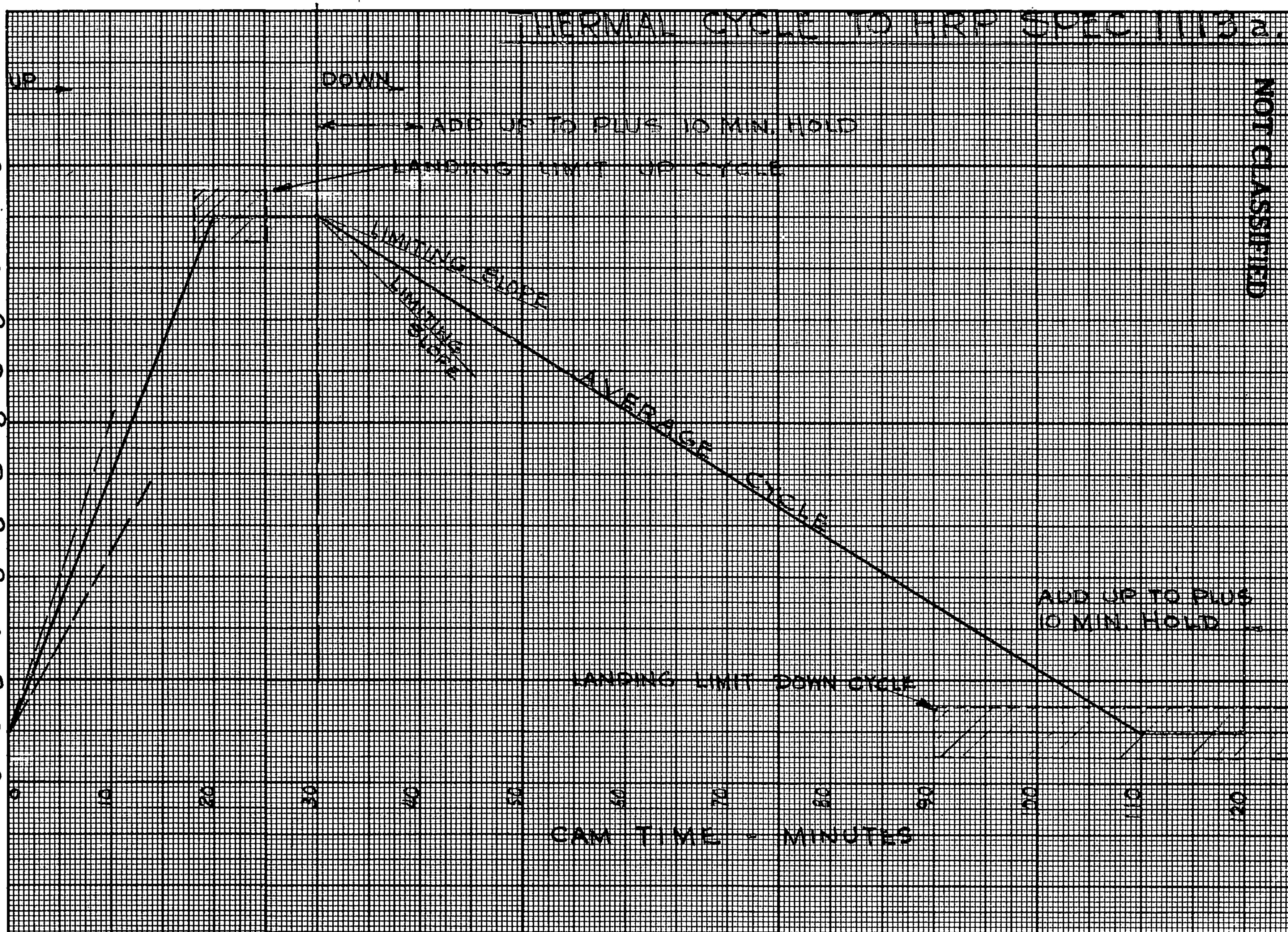


SIMPLEFIED SCHEMATIC

BESLER FLOWSHEET INCL. MAIN THERMAL CYCLE CONTROL

FIG. 2.

FIG. 3



THERMAL CYCLE TO HRP SPEC. 1113 a.
UP
DOWN
ADD UP TO PLUS 10 MIN. HOLD
LANDING LIMIT UP CYCLE
LIMITING SLOPE
LIMITING SLOPE
AVERAGE CYCLE
ADD UP TO PLUS 10 MIN. HOLD
LANDING LIMIT DOWN CYCLE
CAM TEMPERATURE °F
600
580
560
540
520
500
480
460
440
420
400
380
360
0
10
20
30
40
50
60
70
80
90
100
110
120
CAM TIME - MINUTES
NOT CLASSIFIED
ORNL-LR-DWG-27969