Plant Operational challenges starting up 1MW steam turbine generator

Emory University
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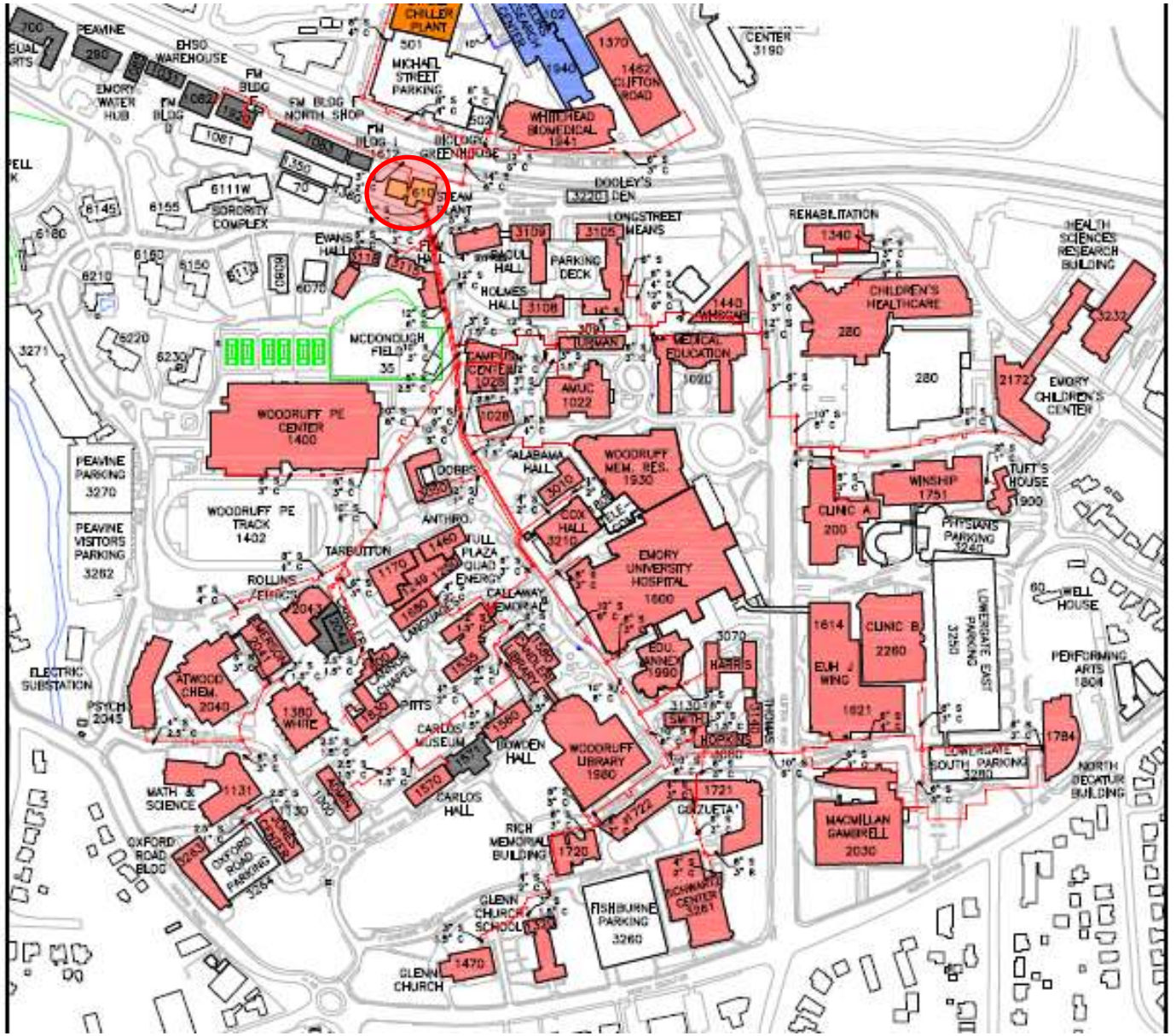
Campus Overview

Emory Overview

- 15,451 students
- 33,026 employees
- Approximately 9 million square feet; 130 buildings
- Central Steam Plant 500,000 pph capacity
- Three Central Chiller Plants 20,300 tons capacity
- Utility budget of approx. $35M

Campus Overview

EQUIPMENT NAME	YEAR INSTALLED	BOILER AGE	CAPACITY
BOILER NO. 6	1975	43	100,000 PPH
BOILER NO. 7	1989	29	100,000 PPH
BOILER NO. 8	1989	29	100,000 PPH
BOILER NO. 9	2001	17	100,000 PPH
BOILER NO. 10	2016	2	100,000 PPH
TOTAL	---	---	500,000 PPH



Overview

- Utility Master Planning
- Design
- Start up & Tuning
- Operations & Maintenance

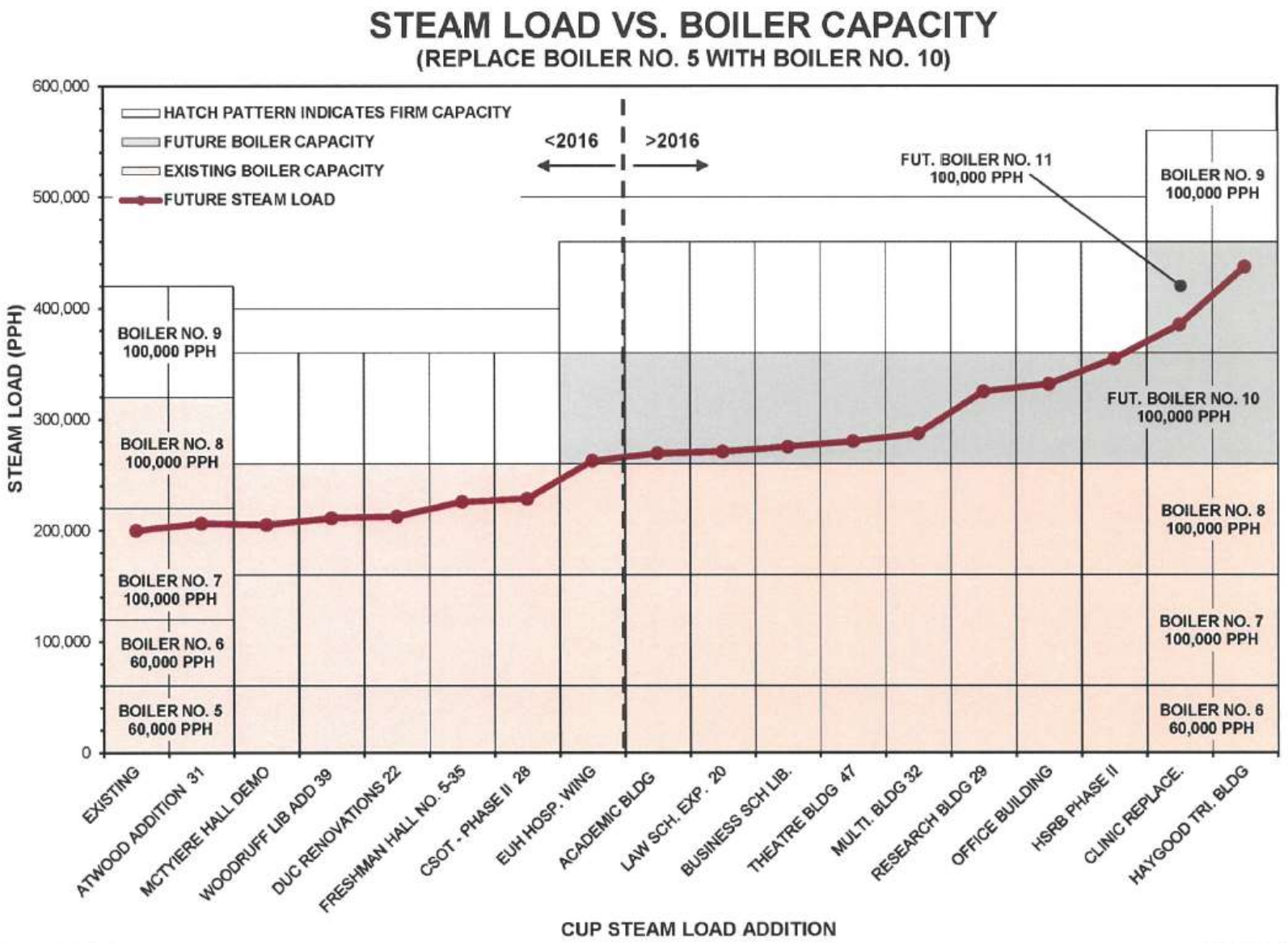
Utility Master Planning

Summary from 2013 Study

Summary

- Future Campus Expansion requires Approx. 180,000 pph additional capacity
- Recommend 100,000 pph boiler initially to replace Boiler No. 5
- Second 100,000 pph boiler not required until final future buildings
- CHP is not cost effective with current rate structure
- If Georgia becomes deregulated and electric costs increase, re-evaluate CHP
- Backpressure Steam Turbogenerator is cost effective (7 year simple payback)
- BP STG would use 250 psig steam generated from Boiler No. 10 nomally generated for campus

Predicted Steam Demand for Future Capacity



Predicted Steam Load increase to 400+ kpph by 2025 due to future expansions

Steam Demand for Future Capacity

FUTURE STEAM LOAD SUMMARY

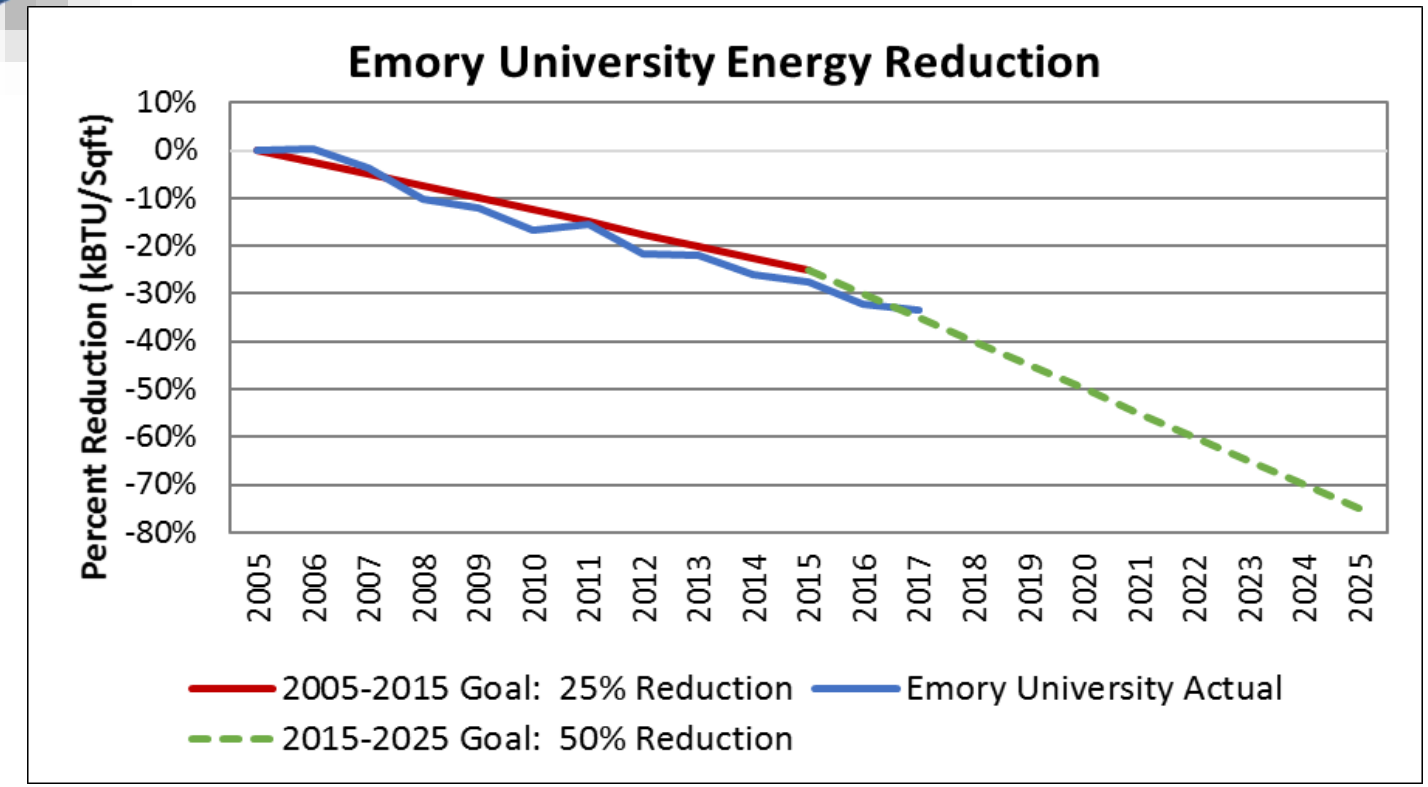
YEAR	BUILDING	GROSS AREA (GSF)	SPACE TYPE	HEATING LOAD			CENTRAL PLANT BOILER PROD. (PPH)
				UNITARY LOAD (B/HR/GSF)	CONNECT. LOAD (PPH)	PEAK LOAD (PPH)	
EXIST	EXISTING	6,864,471	---	66	453,400	184,000	200,000
2013 - 2015	ATWOOD ADDITION 31	65,000	CLASSROOM / OFFICE / LAB	92	6,000	6,000	206,500
	MCTYIERE HALL DEMO	(26,545)	RESIDENCE HALL	(119)	3,150	(1,278)	205,100
	WOODRUFF LIB ADD 39	120,000	LIBRARY	45	5,400	5,400	211,000
	DUC RENOVATIONS 22	25,000	ASSEMBLY	60	1,500	1,500	212,600
	FRESHMAN HALL No. 5 - 35	120,000	RESIDENCE HALL	100	12,000	12,000	225,700
	CSOT - PHASE II 28	65,000	CLASSROOM / OFFICE	40	2,600	2,600	228,500
	EUH HOSPITAL WING	400,000	HEALTHCARE	79	31,400	31,400	262,600
	SUBTOTAL	768,455	---	81	62,050	57,622	---
> 2016	ACADEMIC BLDG	150,000	CLASSROOM / OFFICE	40	6,000	6,000	269,200
	LAW SCH. EXPANSION 20	40,000	CLASSROOM / OFFICE	40	1,600	1,600	270,900
	BUSINESS SCH LIBRARY	80,000	LIBRARY	50	4,000	4,000	275,200
	THEATRE BLDG 47	80,000	ASSEMBLY	59	4,700	4,700	280,300
	MULTIPURPOSE BLDG 32	110,000	ASSEMBLY	58	6,400	6,400	287,300
	RESEARCH BLDG 29	350,000	LAB	100	35,000	35,000	325,300
	OFFICE BUILDING	150,000	OFFICE	40	6,000	6,000	331,900
	HSRB PHASE II	210,000	LAB	100	21,000	21,000	354,700
	CLINIC REPLACEMENT	470,000	HEALTHCARE	60	28,200	28,200	385,300
	HAYGOOD TRIANGLE BLDG	800,000	HEALTHCARE	60	48,000	48,000	437,500
	SUBTOTAL	2,440,000	---	66	160,900	160,900	---
TOTAL		10,072,926	---	67	676,350	402,522	437,500

- Complete
- Reduction instead of increase
- Active Design

Actual increase due to expansions equal to 50 kpph.

Other expansions currently in progress add another 56 kpph

Energy Conservation



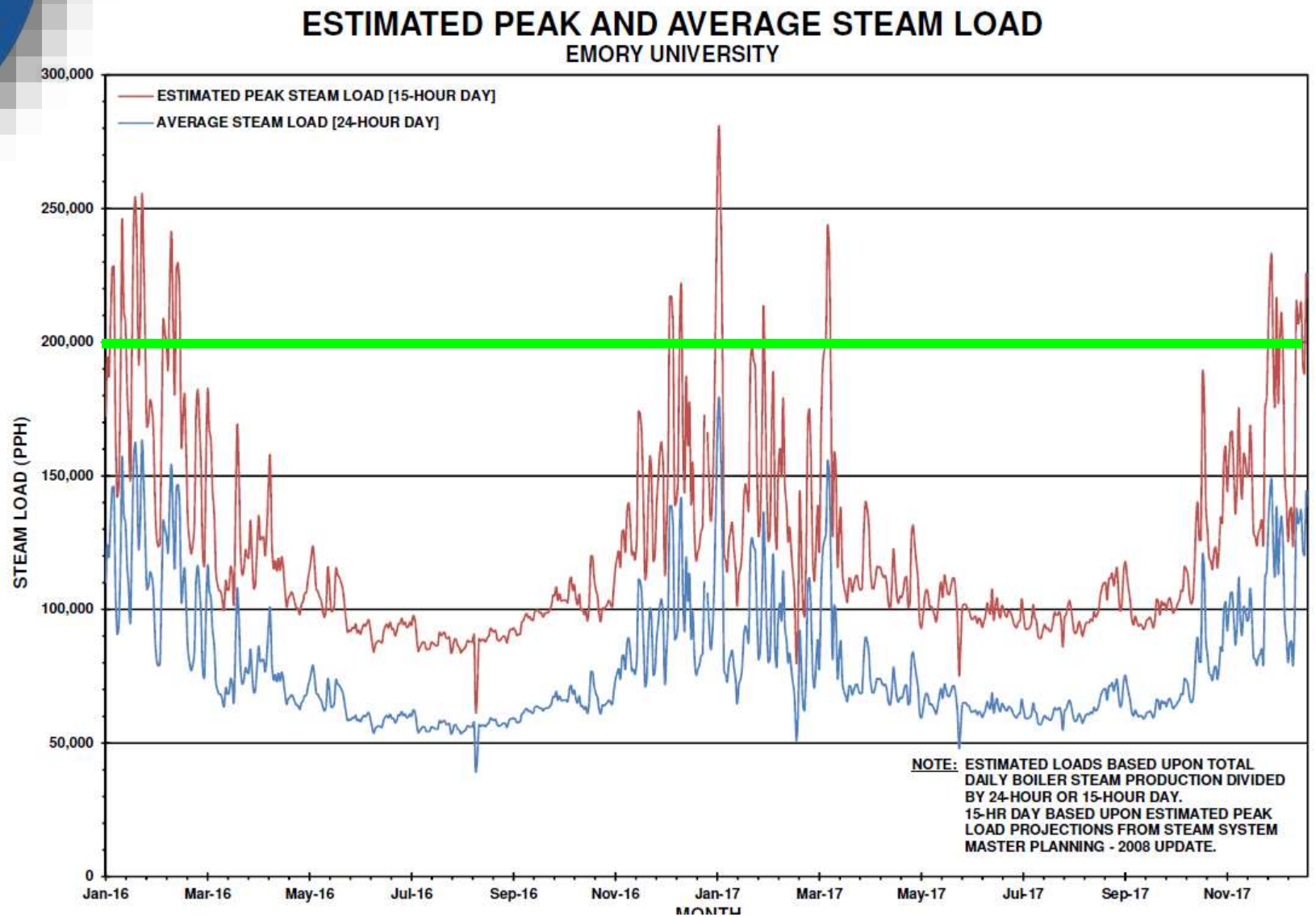
The 2025 Goals (with a 2015 Baseline) are to reduce:

- Total Energy Consumption 25% to 1.2 million mmBtu.
- Energy Use Intensity (EUI) by 50% to 137.5 kBtu/sqft.
- Potable Water Consumption by 50%.

Since 2005, Emory has reduced EUI by 33.6%.

Through energy reduction initiatives and commitment to lower EUI for new construction, Emory has reduced energy consumption an additional 10% since 2013

Campus Annual Steam Demand



Energy reduction efforts have more than offset expansions and new construction.

Campus load has decreased over the last several years.

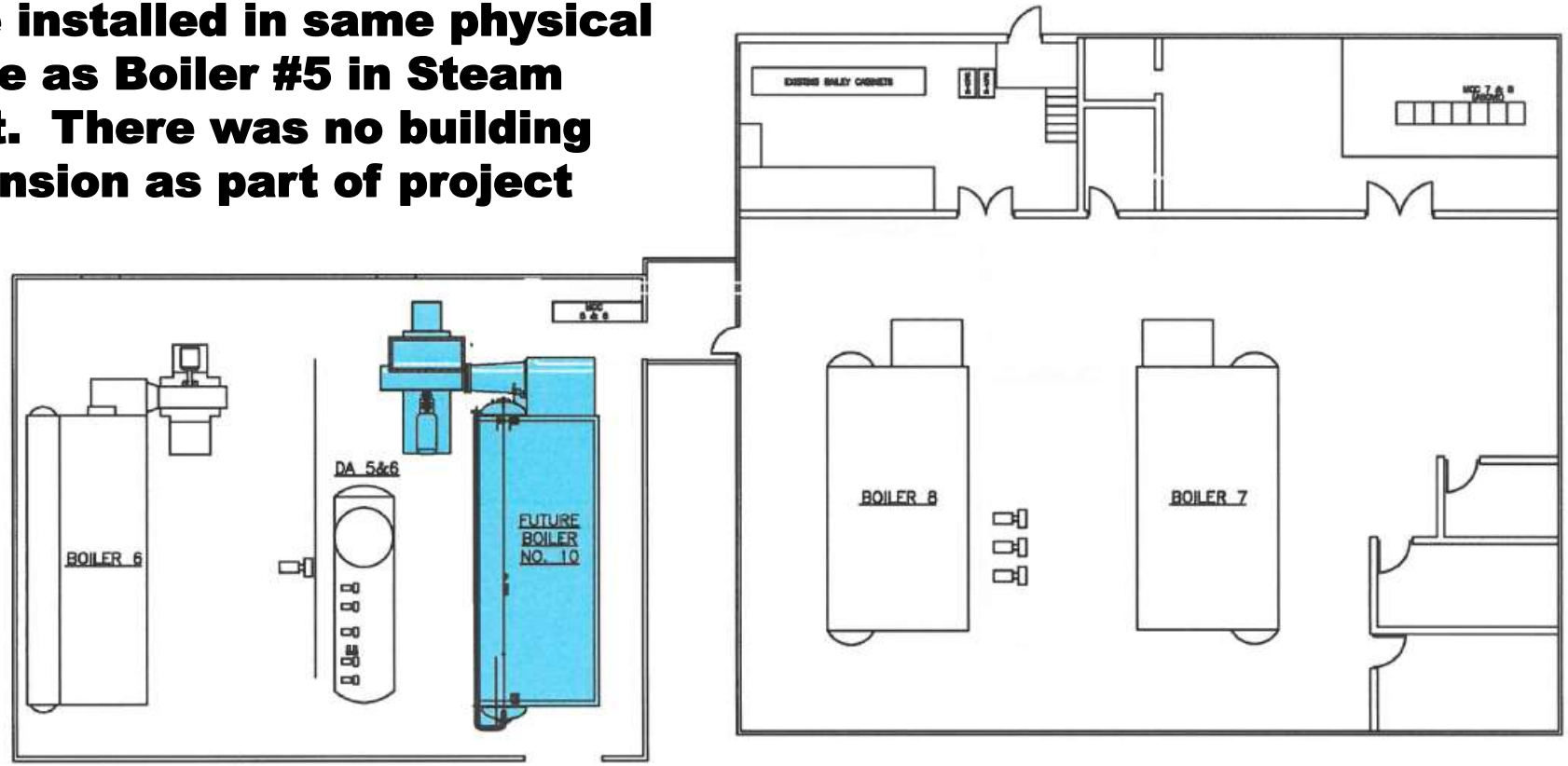
This trend is expected to continue.

Design

Plant Overview

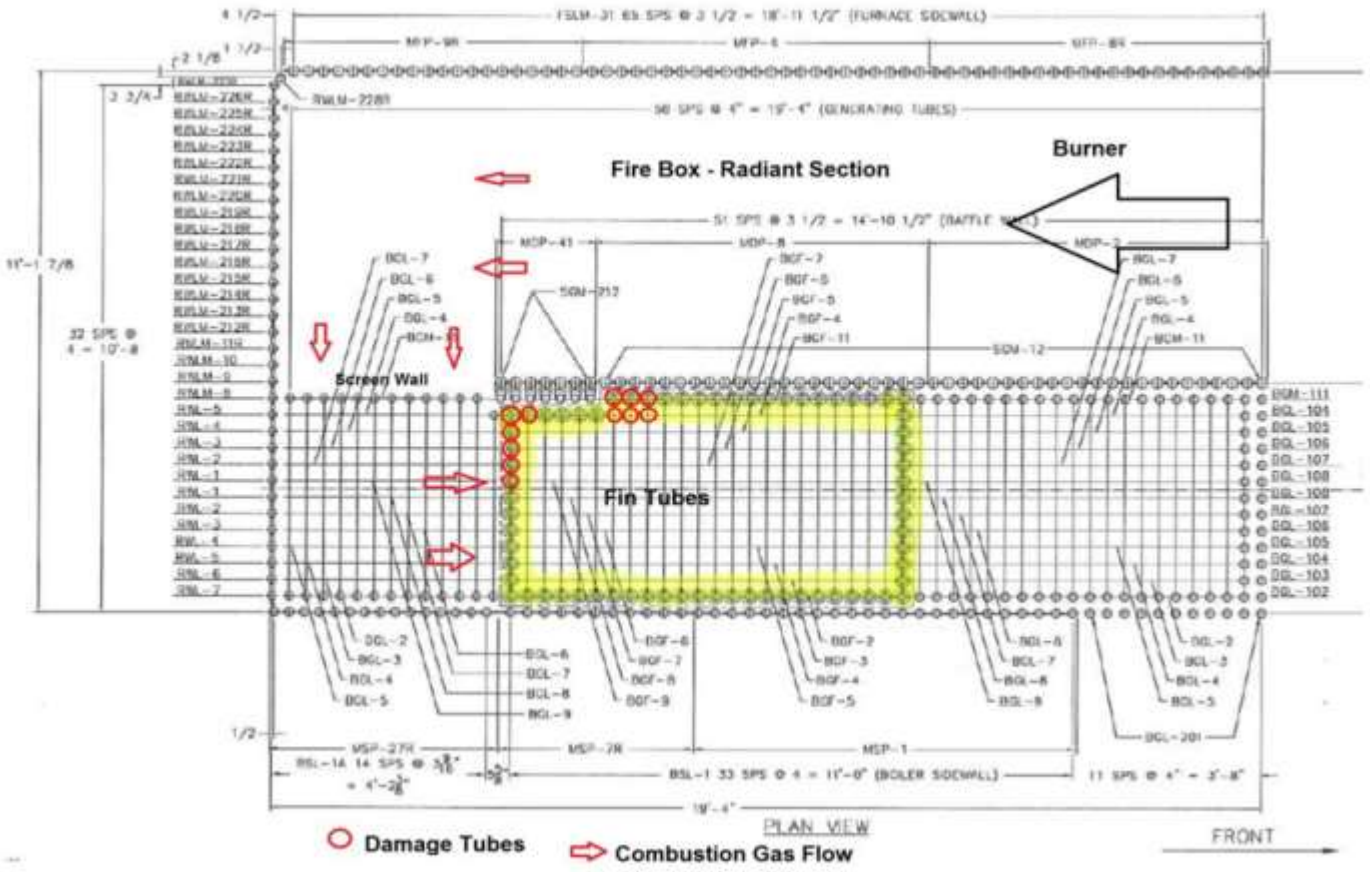
Future Boiler No. 10 Floor Plan

Boiler #10 and Steam Turbine were installed in same physical space as Boiler #5 in Steam Plant. There was no building expansion as part of project



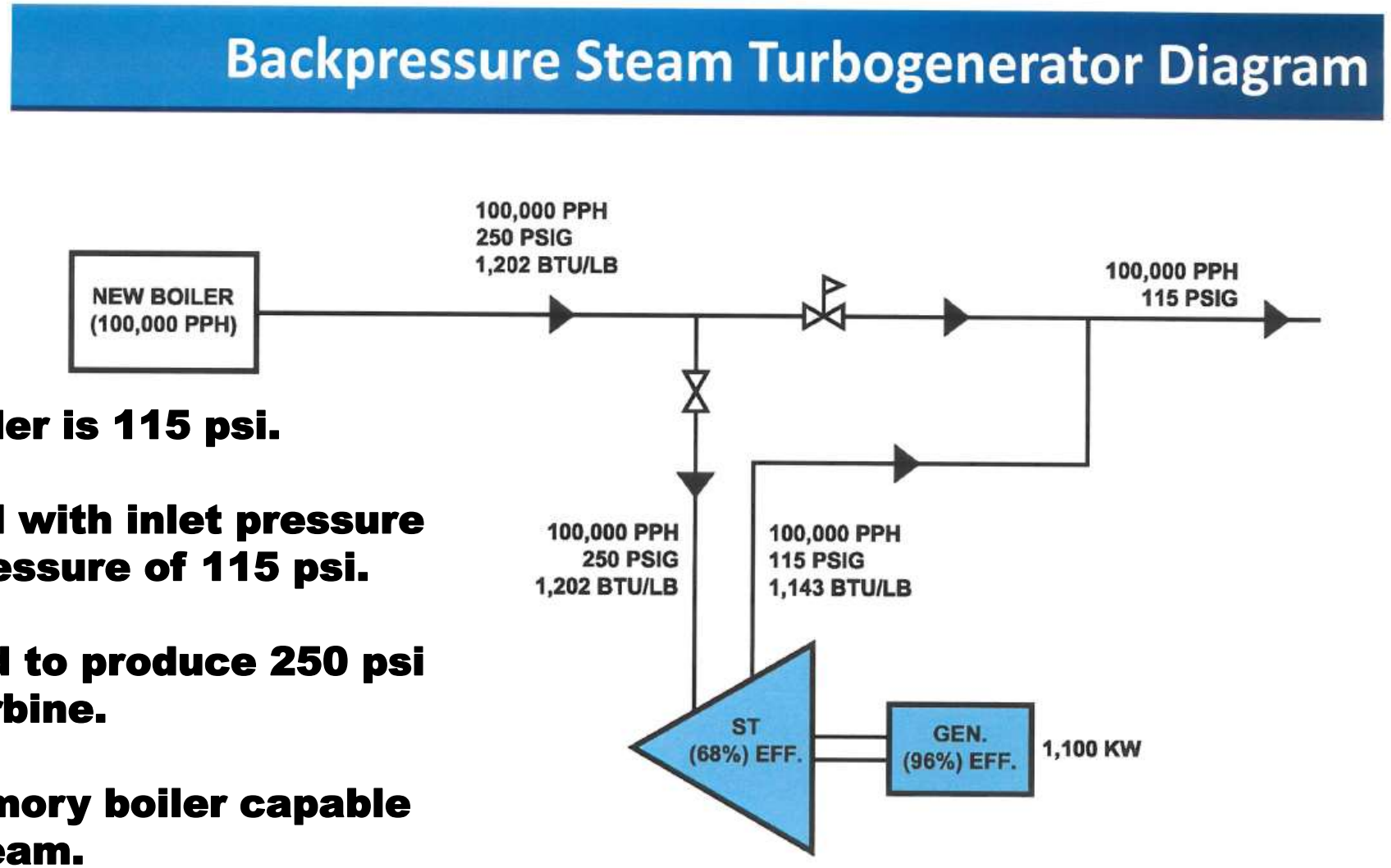
Boiler #10 Tube Damage

- Emory physical and performance requirements in design proposal resulted in a deviation from standard OEM design and having finned tubes in boiler
- First annual overhaul revealed fin damage from heat/flame



Boiler #10 and STG

- **Emory main steam header is 115 psi.**
- **Steam Turbine designed with inlet pressure of 250 psi and outlet pressure of 115 psi.**
- **Boiler #10 was designed to produce 250 psi steam to feed steam turbine.**
- **Boiler #10 is the only Emory boiler capable of producing 250 psi steam.**



DESIGN

- Summertime demand can go below 50,000pph, turbine minimum load is 40,000pph
- Kw output from turbine can only be maximized a few months per year
- No kw production when Boiler #10 is down for overhaul or unplanned maintenance

Start-Up & Tuning

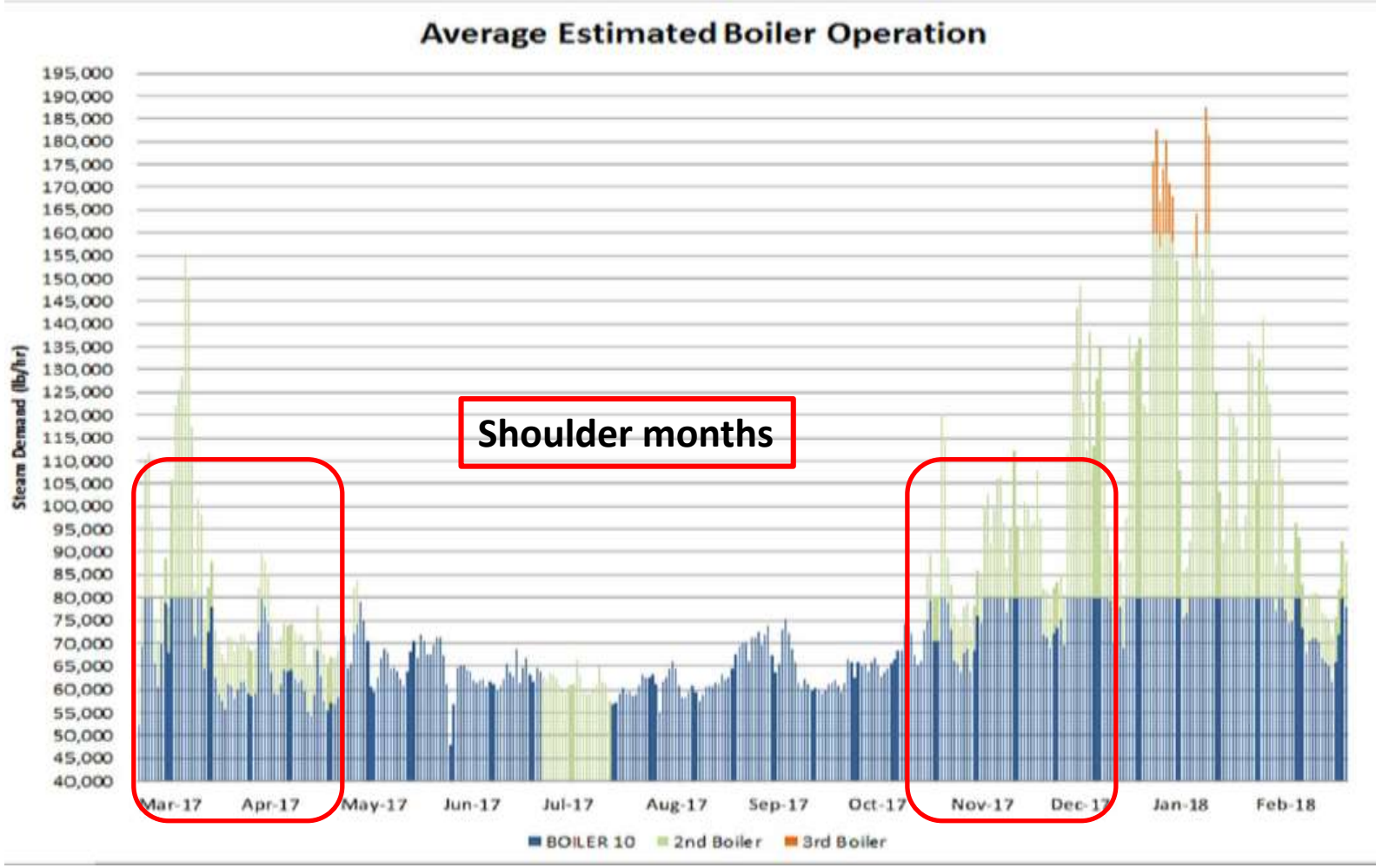
Tuning

- Initial start-up tuning on control loops was not responding appropriately for campus demand
- Experienced many boiler trips and loss of steam to campus during first year in operation
- Combination of turbine response, boiler response and operator intervention (how many steam valves open, how many boilers online)
- Maintenance contractor, Elliott (not part of install), reviewed and adjusted steam inlet valve reaction timing and we have had significant improvement

Operations & Maintenance

Efficiency vs Reliability

- Major change in operating philosophy for operators
  - Maximize turbine kw output vs stability of steam supply
  - Multiple boiler vs one boiler operation

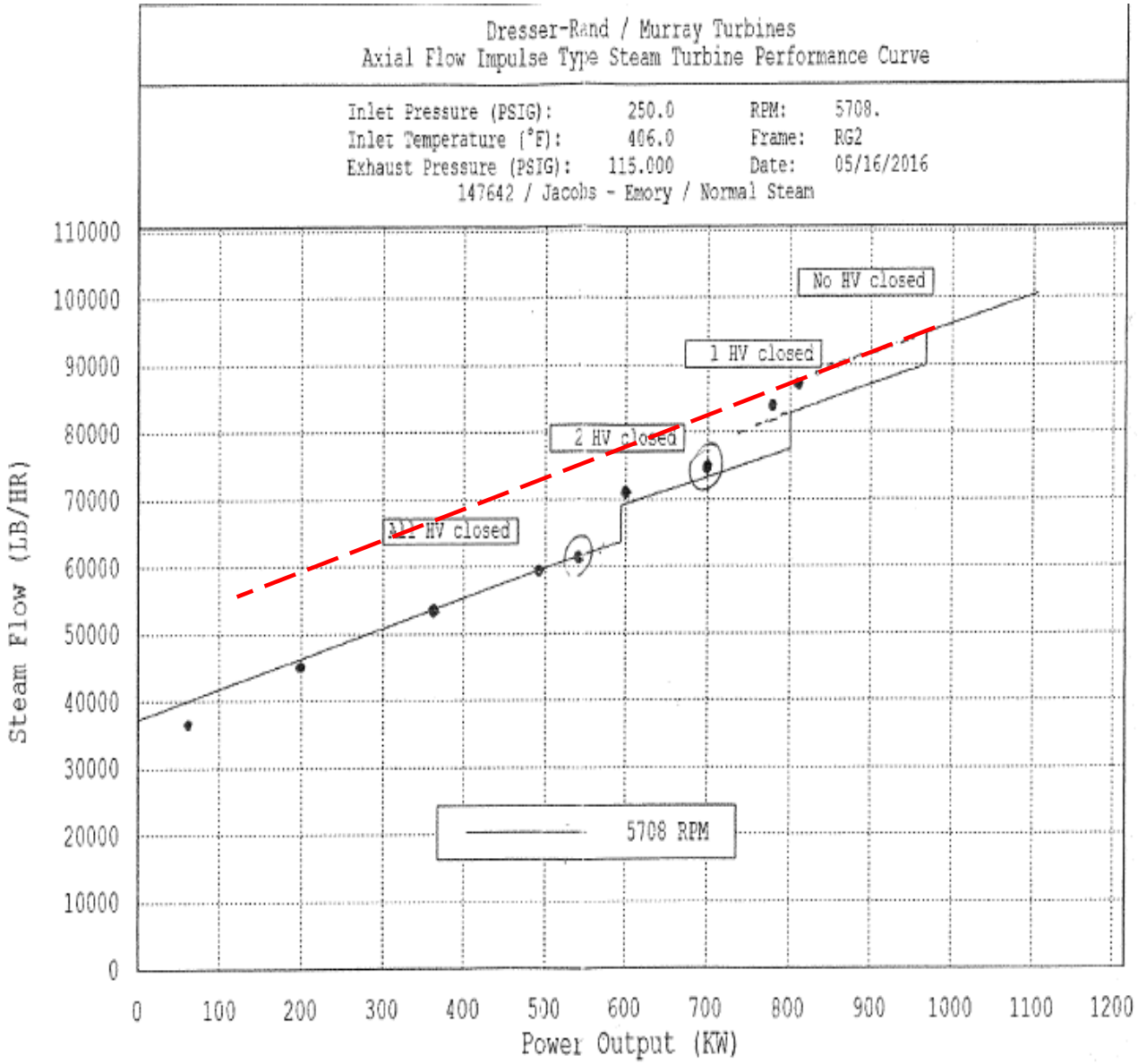


One Boiler Operation

- Increased opportunities for boiler trip and loss of steam supply to customers
- Building demand and system tuning becomes more critical
  - Hospitals and bad tuned control loops cause rapid demand changes have bigger impact at steam plant
  - Largest demand swings due to weather / HVAC needs
  - Overnight low temperatures and start of the day heating demand sees biggest load swings

Manual Operation of Turbine Steam Valves

- Monitor plant load to determine what was best timing to open or close valves
- Running with valves closed increases kw output but limits throughput (system stability issue)
- Running with all valves open maintains throughput but significantly reduces kw output



Operations & Maintenance

- Keeping 4 other boilers active and in rotation has become a challenge
- Similar issue with 2 separate DA tanks
- Operator and maintenance access challenges due to footprint
- No overhead crane for maintenance
- Reused existing orifice plate flowmeters resulting in less accurate metering

Figure B-2 Yearly Steam Demand – Boilers 6, 7, 8 and 9

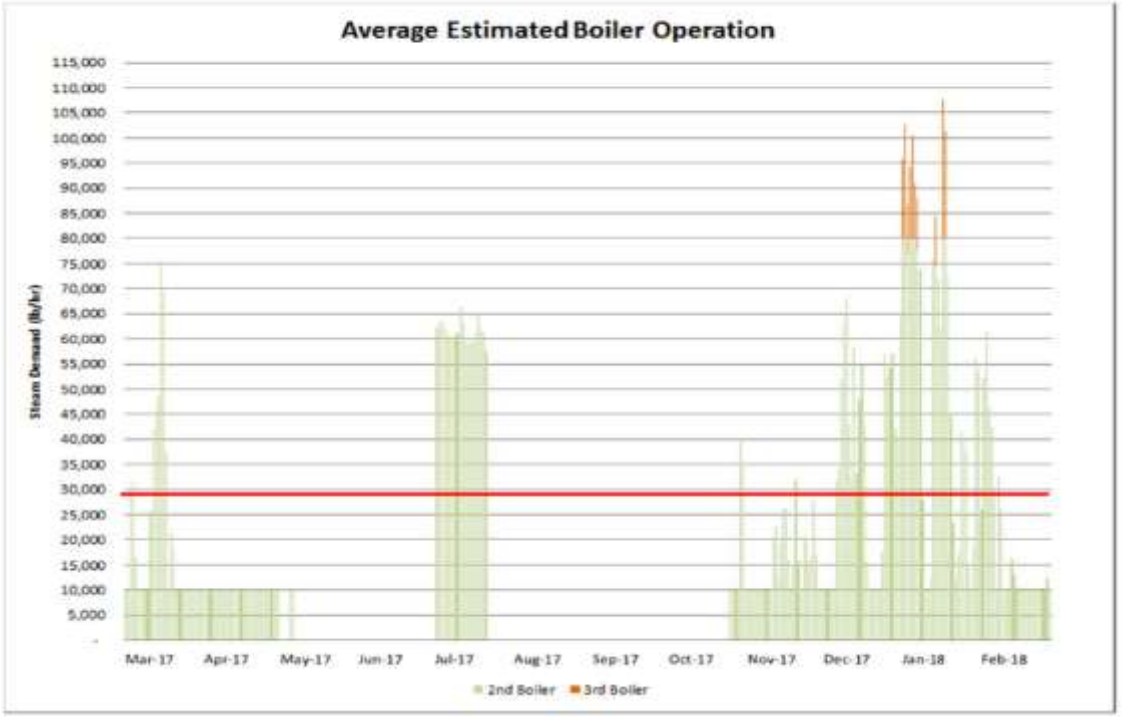
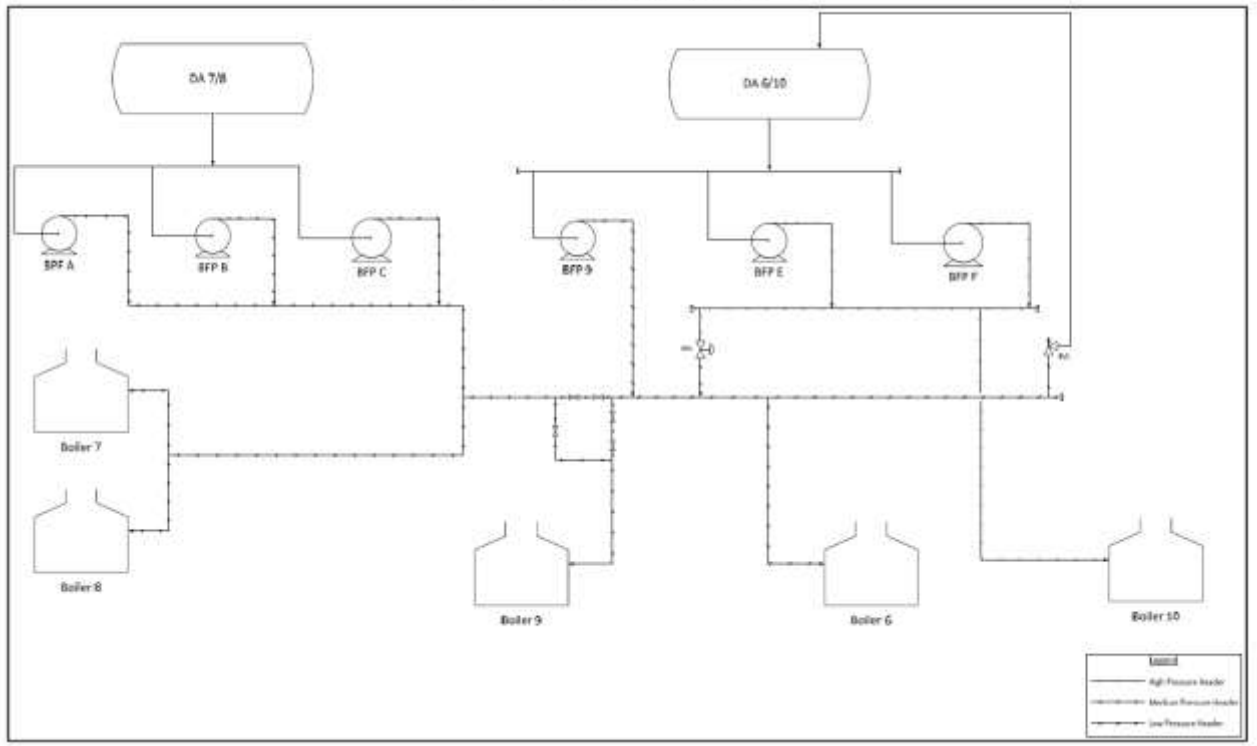


Figure 1 – System Process Flow Diagram



Lessons Learned

- **Utility Master Planning**
  - Incorporate energy reduction impact into future load forecasting
- **Design**
  - Involve all end users in up front design considerations, review how system will be operated and get with other universities/companies on lessons learned ahead of design
- **Start up & Tuning**
  - After one year of operation, re-evaluate system dynamics and tuning to optimize
- **Operations & Maintenance**
  - Have a game plan to maximize efficiency and not sacrifice reliability. Document and Communicate!

THANK YOU!

QUESTIONS?