INTRODUCING SYNCH-CONDENSE MODE:

SUCCESSES AND LESSONS LEARNED

TYLER BRAUN
GENERATION MECHANICAL

5/17/2017

WHY THIS TOPIC?

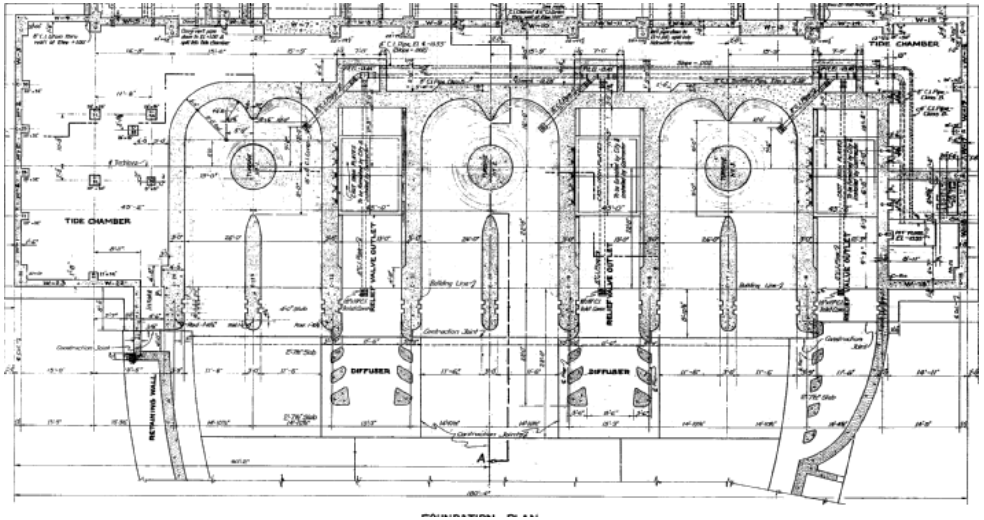
- Changing markets demand additional flexibility.
- Changing markets emphasize capacity (product).
- Low energy prices force utilities to find new efficiencies and income streams.
- Runner replacements, in some instances, retain the original (or result in increased) cavitation and/or rough zones.

TACOMA POWER
TACOMA PUBLIC UTILITIES

PROBLEM STATEMENT

- **3 x 30-MW, vertical, Francis units at Cushman #2;**
- **8-MW lower limit on all due to cavitation concerns;**
- **Site has had a low (~30%) capacity factor since runner replacements in the mid-90s.**

<u>How can we operate more efficiently to increase revenue and decrease maintenance?</u>



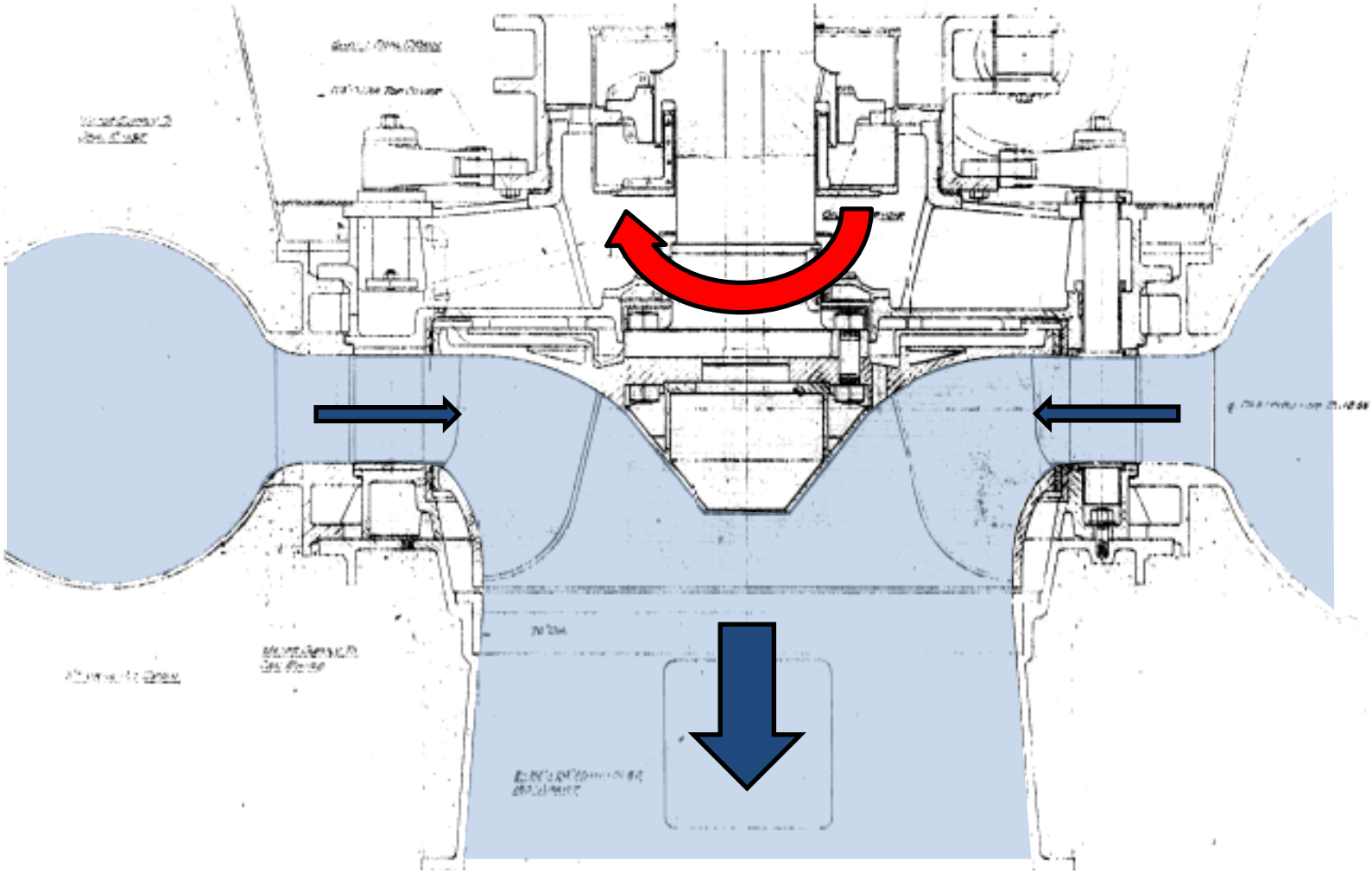
WHAT IS SYNCH-CONDENSE MODE?

- **The rotation of a synchronous machine is synchronized with the frequency of the supply current.**
- **A synchronous machine can be operated as a generator or as a motor;**
- **Without input to the prime mover, it necessarily operates as a motor.**

<u>How does this apply to hydro?</u>

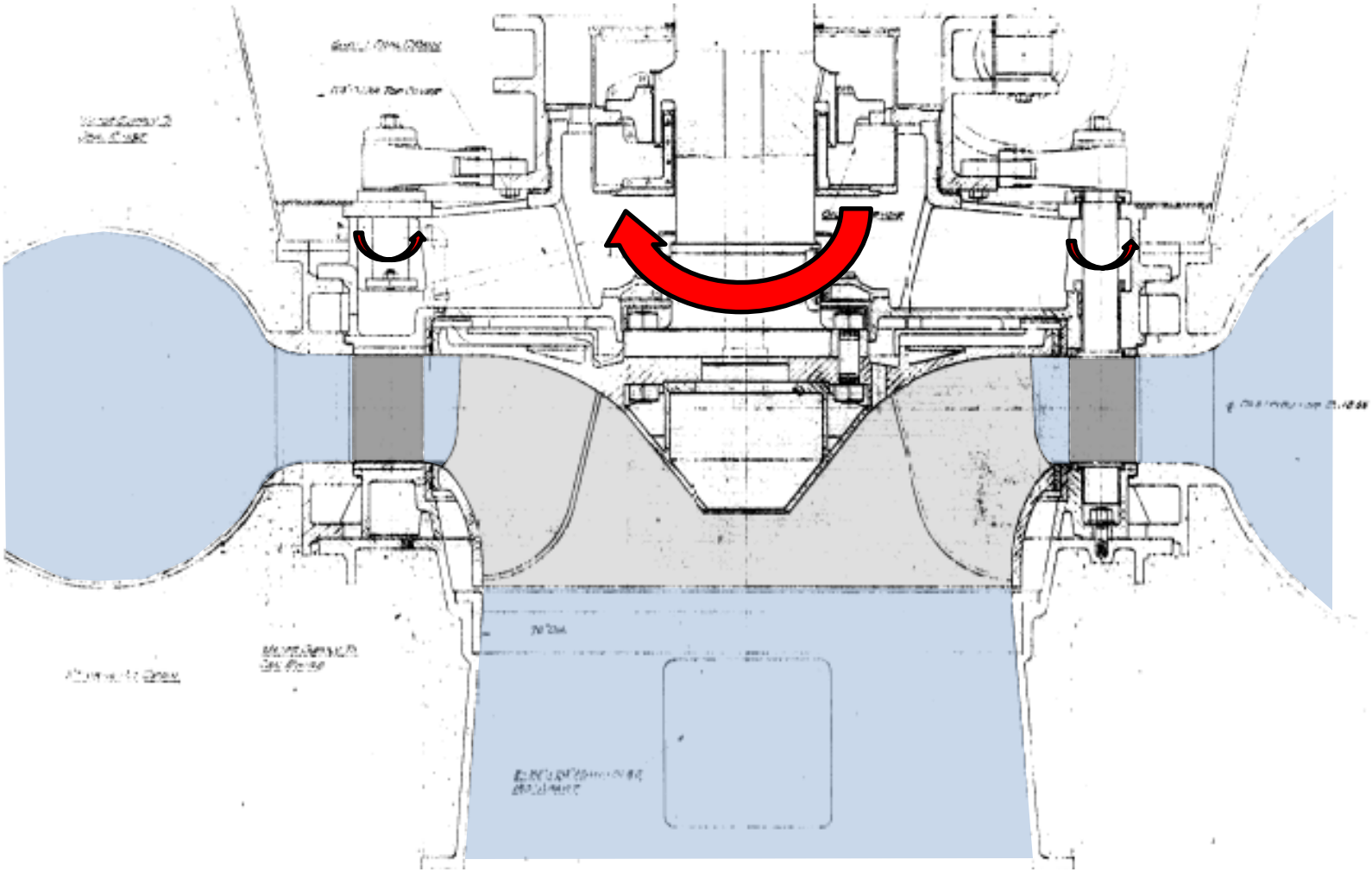
TACOMA POWER
TACOMA PUBLIC UTILITIES

WHAT IS SYNCH-CONDENSE MODE?



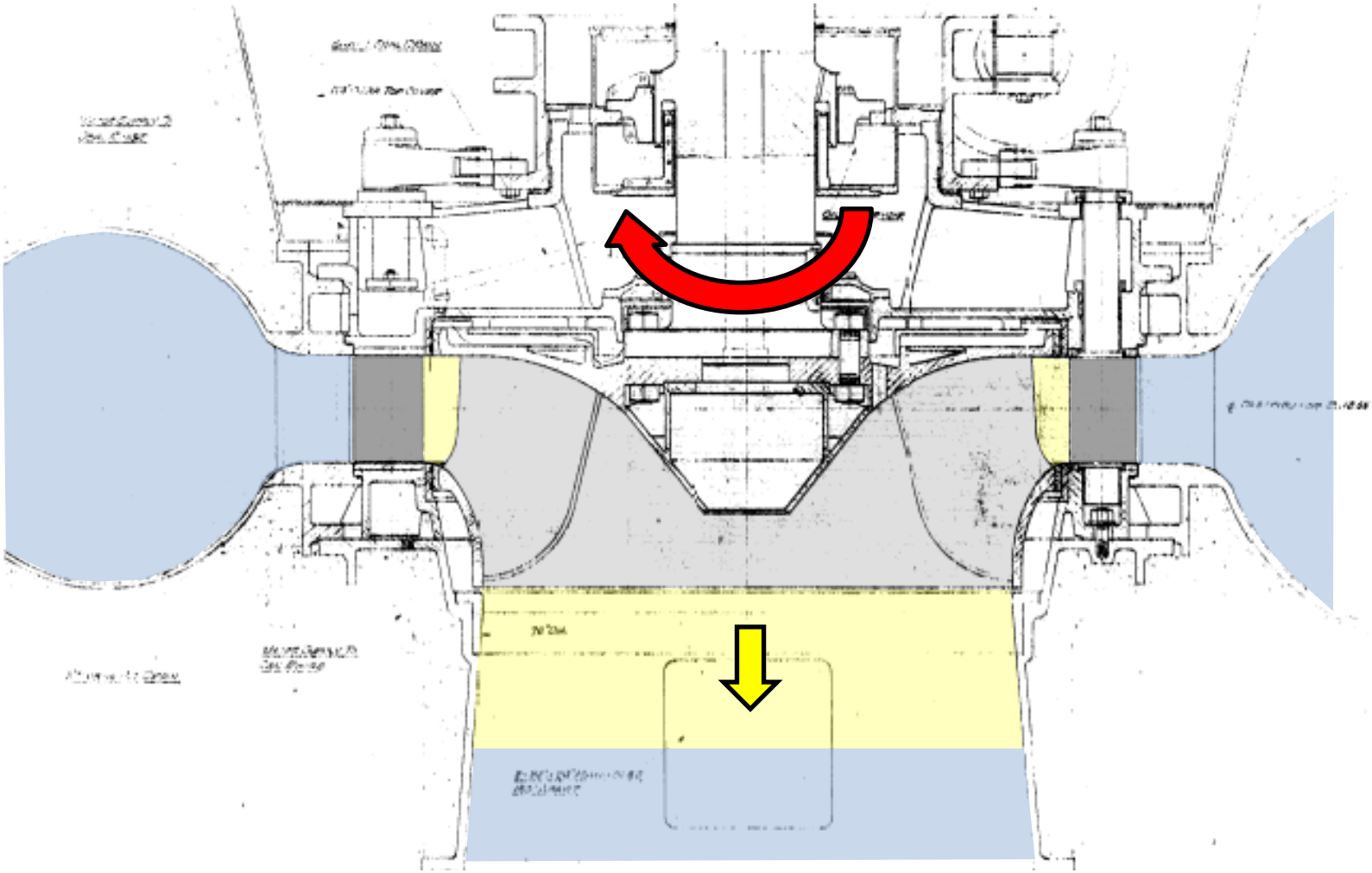
TACOMA POWER
TACOMA PUBLIC UTILITIES

WHAT IS SYNCH-CONDENSE MODE?



TACOMA POWER
TACOMA PUBLIC UTILITIES

WHAT IS SYNCH-CONDENSE MODE?



TACOMA POWER
TACOMA PUBLIC UTILITIES

SCREENING EFFORT

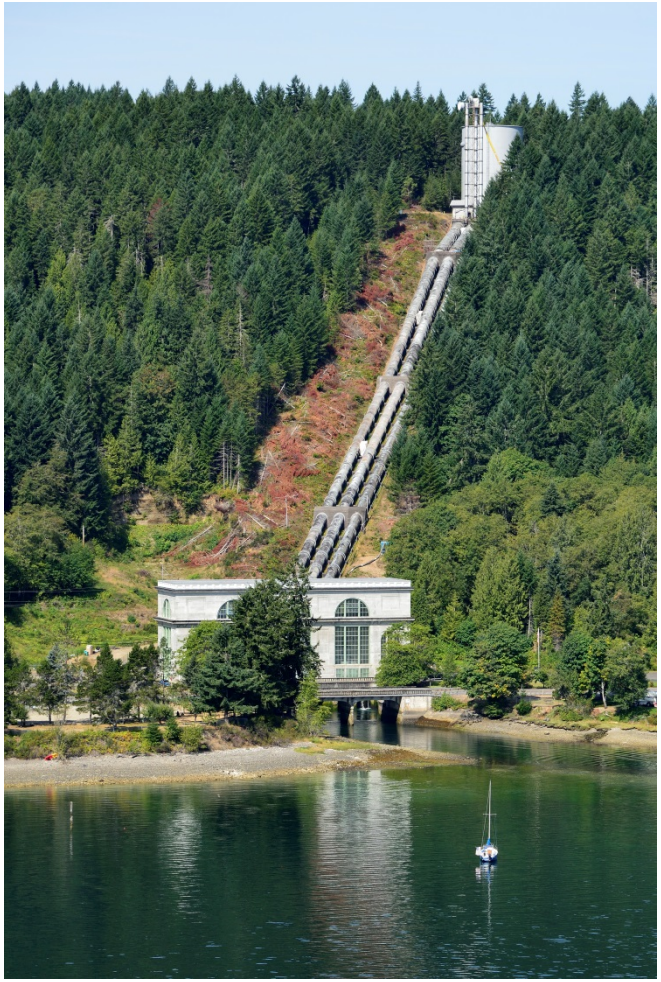
An internal feasibility study and report, circa 2008, found that the following modifications/additions would be necessary at Cushman #2:

- **Plant control system;**
- **Unit relay protection;**
- **"Turbo vent" and/or air-injection system.**

TACOMA POWER
TACOMA PUBLIC UTILITIES

SITE-SPECIFIC CONCERNS

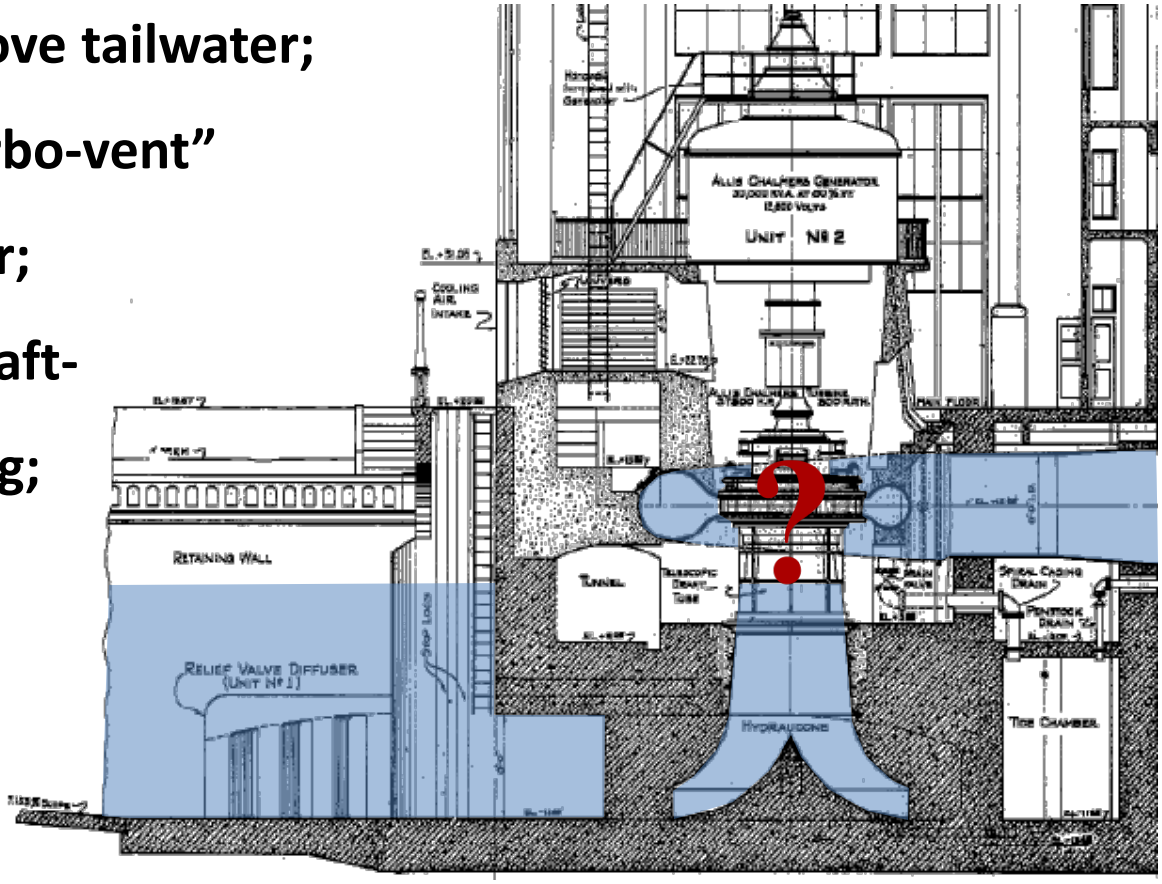
- <u>TIDAL</u> tailwater on Hood Canal;
- Turbine-inlet valves;
- U31/32: Leaky wicket gates and penstock relief valves;
- U31/32: No water supplied to runner crown/band seals;
- U33: 2010 blade crack.



TACOMA POWER
TACOMA PUBLIC UTILITIES

ATTEMPT 1: VENT VALVE(S)

- Runner usually above tailwater;
- Cam-operated "turbo-vent" valve on headcover;
- Manual valve in draft-tube air-vent piping;
- <u>Neither</u> lowered motoring load!



TACOMA POWER
TACOMA PUBLIC UTILITIES

ATTEMPT 2: BLOWER

Purchased & installed low-pressure blower:

- **Pressure adequate (<5 psig);**
- **Depression time too slow (5+ min);**
- **Air frothed and disappeared into the tailrace;**
- **Noisy – plant staff and neighbors complained!**

ATTEMPT 3: COMPRESSOR/TANK

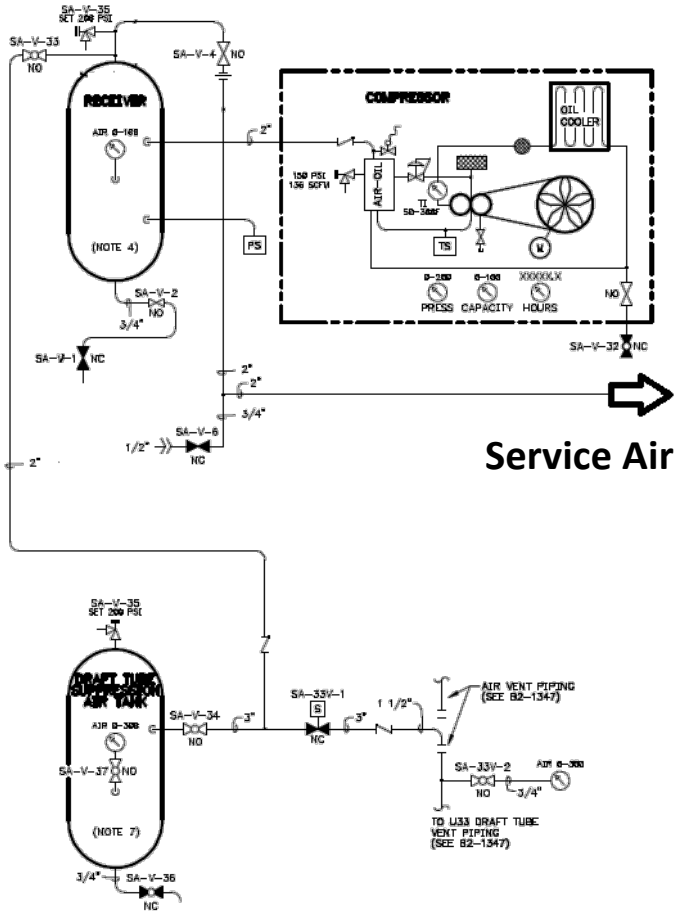
While engineering was busy with literature review and calculations regarding a higher-pressure air supply, the plant manager had staff connect the unit to the existing service-air system…

- **System fed air service drops only;**
- **No connection to governor air, brake air, shear-pin-failure detection, etc.;**
- **<u>Success!</u>**

TACOMA POWER
TACOMA PUBLIC UTILITIES

COMMERCIAL SYSTEM

- Retained air source;
- New 500-gal tank (~2.5 draft-tube volumes);
- 115-psig operating pressure;
- 15-second depression time;
- Governor, protection, & control changes, including a new operating mode: “condense.”



TACOMA POWER
TACOMA PUBLIC UTILITIES

SUMMARY OF COSTS

$20k in material/equipment:

- **New air tank, piping, & solenoid valve.**

Internal (O&M) labor:

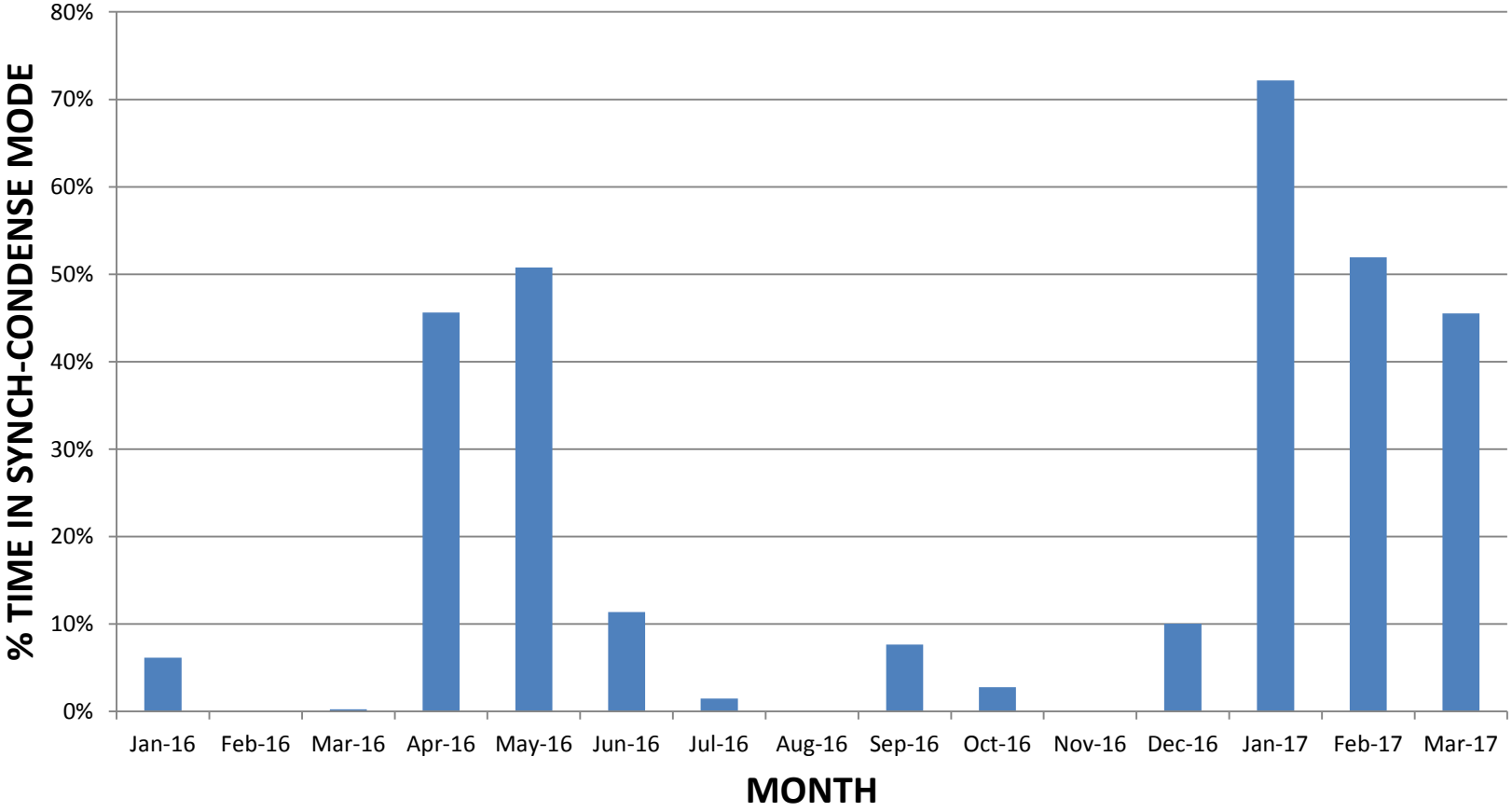
- **Design and testing;**
- **Controls, relay and protection work.**

Significant savings:

- **Air supply system;**
- **Unit diassembly/modifications.**

TACOMA POWER
TACOMA PUBLIC UTILITIES

FREQUENCY OF USE



TACOMA POWER
TACOMA PUBLIC UTILITIES

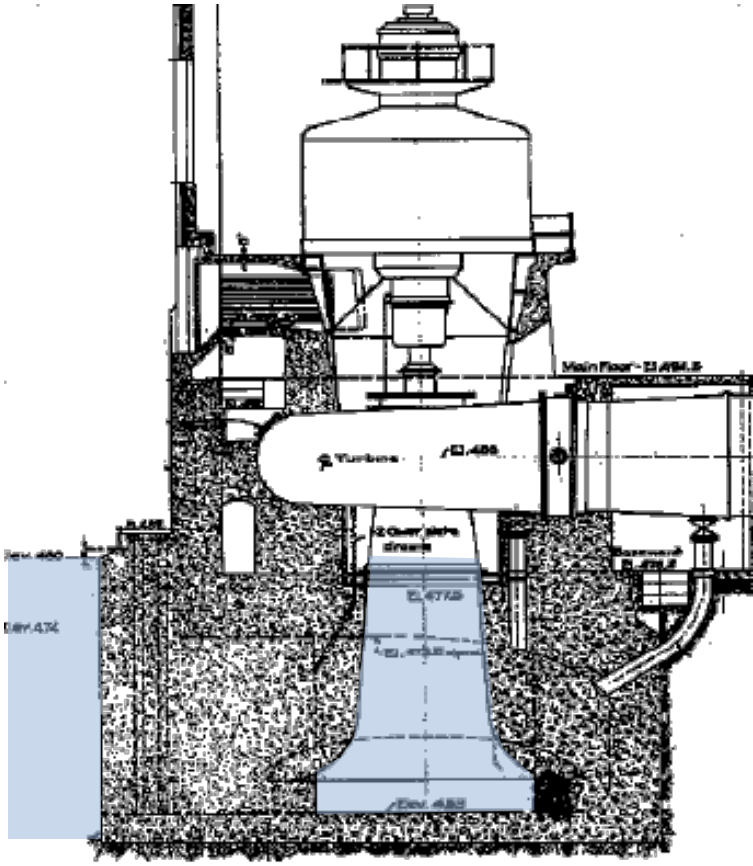
VALUE

- Opportunity cost of operating at minimum load due to reduced efficiency;
- Additional capacity product;
- Reduced maintenance benefit:
  - Cavitation damage when <= 25% load;
  - # of start/stop cycles.

TACOMA POWER
TACOMA PUBLIC UTILITIES

APPLICATION TO OTHER UNITS

- **Immediate, positive reaction!**
- **Requests for other units…**
- **Unit 22 (Cushman #1):**
  - **Reviewed 1955 report;**
  - **Installed in 2016;**
  - ***No sealing water provided!***
  - **Removed in 2017.**



TACOMA POWER
TACOMA PUBLIC UTILITIES

LESSONS LEARNED

- Plan for functionality early:
  - Controls upgrades;
  - Turbine disassembly.
- Specify runner seal water for “motoring”;
- Machine behavior may not match expectations;
- Test before purchasing/installing permanent equipment, when possible;
- Simpler can work:
  - MW setpoint instead of level instruments;
  - Use of existing air supply.
- Anticipate future requests related to other units.

TACOMA POWER
TACOMA PUBLIC UTILITIES

REFERENCES

- Berger, “Synchronous Condensers: Background”, Waterpower ’99, Las Vegas, July 1999.
- Department of the Army. U.S. Army Corps of Engineers. *Hydroelectric Power Plants Mechanical Design* (EM 1110-2-4205). 1995.
- Dingman and Harrison, “Synchronous Condensers: Installation and Operation” Waterpower ’99, Las Vegas, July 1999.
- Eyden and Slack. "Analysis and Solution of a Draft-Tube Water Depression Problem." *J. Eng. Power* 89.4 (1967): 529-38.
- Paul and Evans, “ Synchronous Condensers: Design and Testing” Waterpower ’99, Las Vegas, July 1999.
- Pawlikewich. "Operating Units as Synchronous Condensers: Experiences with Converting Seven Sisters." *Hydro Review* Apr. 2006: 53-57.

TACOMA POWER
TACOMA PUBLIC UTILITIES

QUESTIONS?

TYLER BRAUN
TACOMA POWER
GENERATION MECHANICAL
(253) 502-8658
TBRAUN@CITYOFTACOMA.ORG

TACOMA POWER
TACOMA PUBLIC UTILITIES