SAYANO-SHUSHENSKAYA

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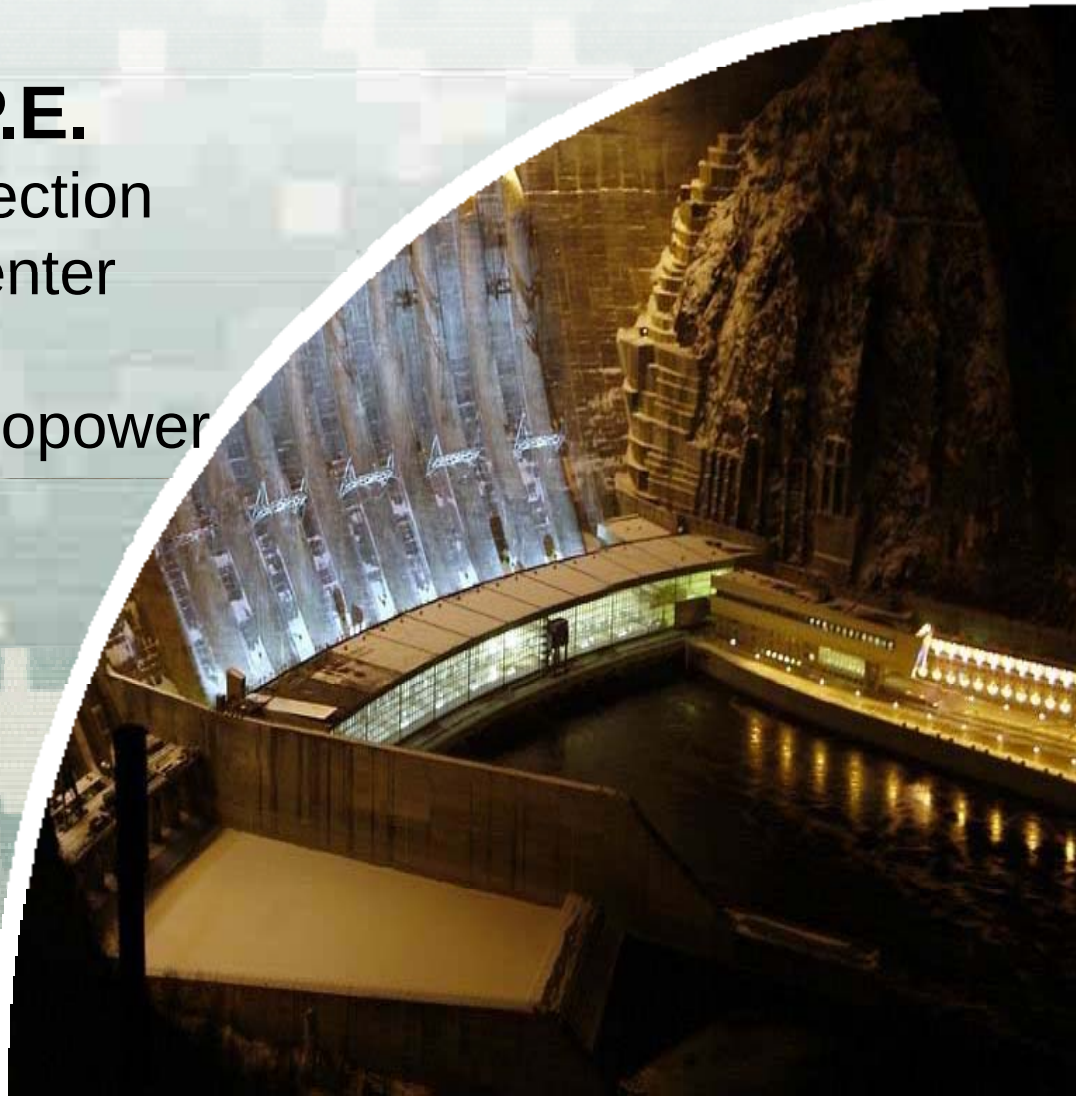
US Army Corps of Engineers
BUILDING STRONG



Russian Hydropower Accident

The slides that follow were taken from many different sources and represent the facts as we know them (Note: Information is sparse and sketchy). This presentation is for internal use only.

Sayano-Shushenskaya Unit 2 Failure

Sayano-Shushenskaya, Russian Hydro Powerhouse

The Plant

- Powerhouse: Sayano-Shushenskaya
- Owner / Operator: RusHydro
- Installed Capacity: 6400 MW. Largest power plant in Russia and the world's sixth-largest hydroelectric plant by average power generation.
- Construction started in 1968
- Power on Line (POL): 1978

The Dam

- Type: Arch (Looks like Hoover)
- Height: 245.5 meters (805 ft) high
- Crest Length: 1,066 meters (3,500 ft)
- Crest Width: 25 meters (82 ft)

Sayano-Shushenskaya

Sayano-Shushenskaya, Russian Hydro Powerhouse

The Dam

Sayano-Shushenskaya, Russian Hydro Powerhouse

The Turbine

- Francis type turbines
- Unit Rating: 640 MW each
- Number of Units: 10
- Rated Head: 194 meters (640 ft) (275 psi)
- Max Head: 220 meters (720 ft) (310 psi)
- Unit Flow: 340 to 360 m^3/s (12,000 cfs to 12,700 cfs)
- Unit Speed: 142.8 RPM

Videos

Eyewitness Video - http://www.youtube.com/watch?v=egeABBr5hyA

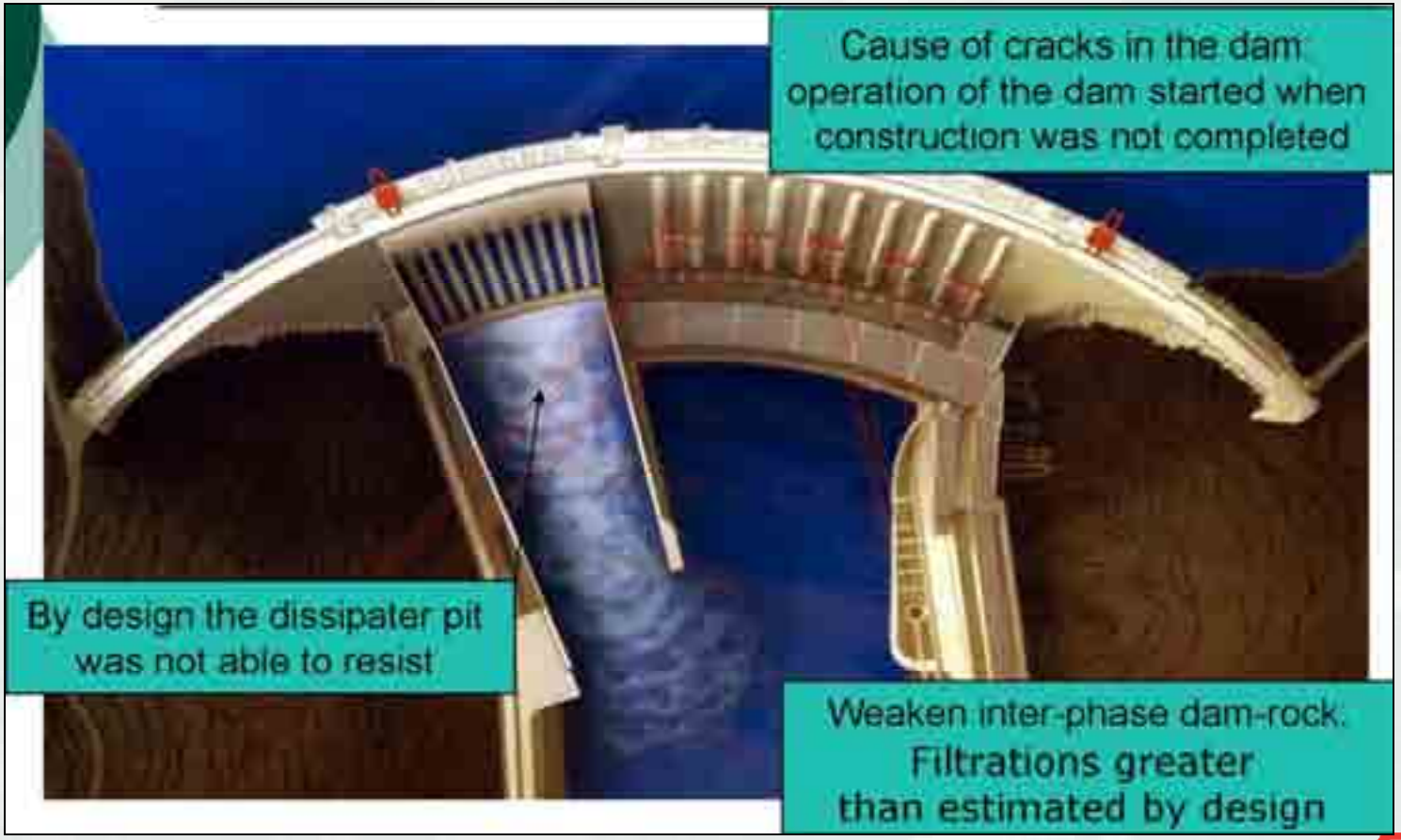
CCTV Footage - http://www.youtube.com/watch?v=R1q-tiSWudw

Videos

Videos


РИАНОВОСТИ
РОССИЙСКОЕ АГЕНТСТВО МЕЖДУНАРОДНОЙ ИНФОРМАЦИИ

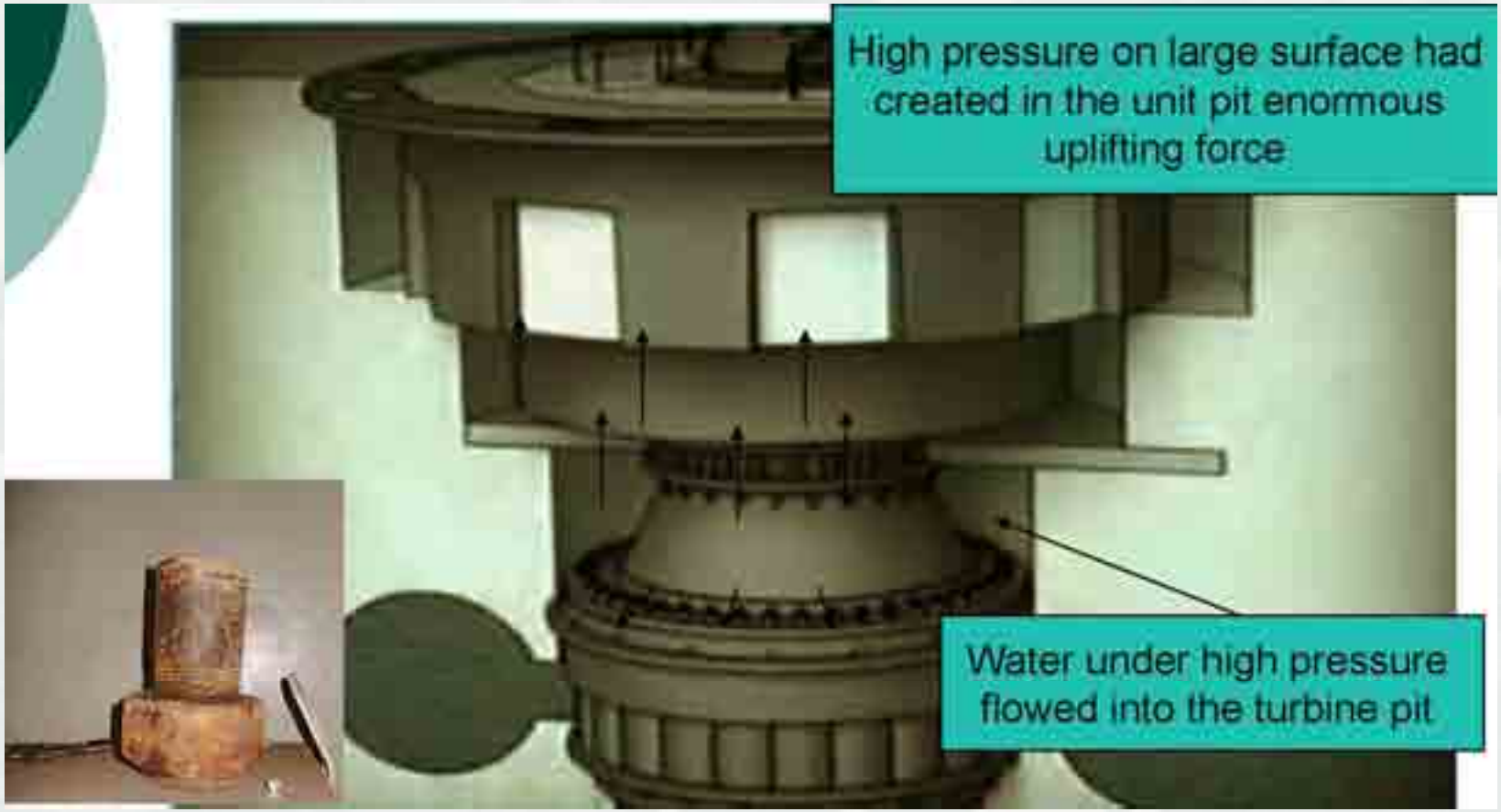
Major Issues of the Dam



Inside of the Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

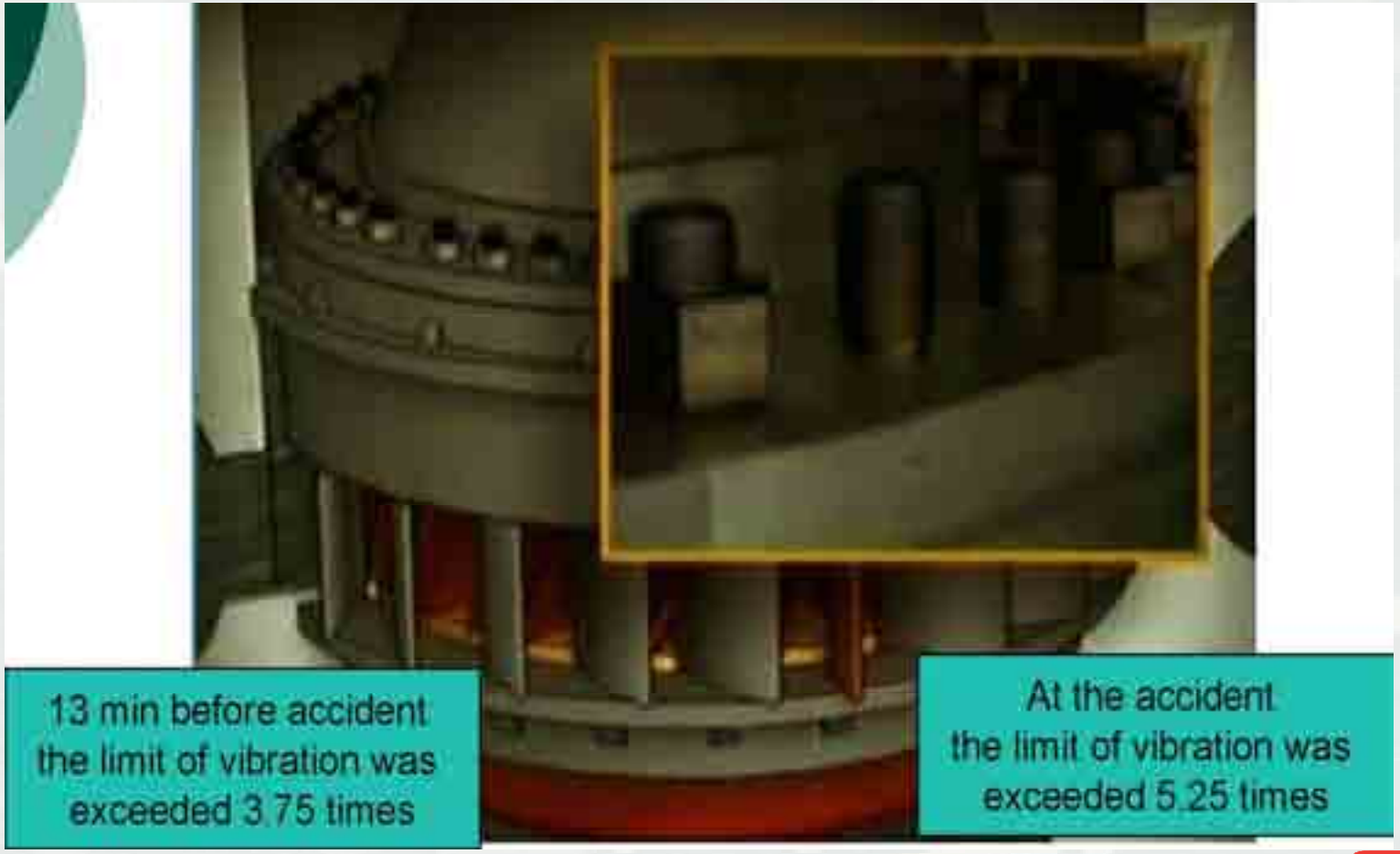
Turbine Unit



Sayano-Shushenskaya, Russian Hydro Powerhouse

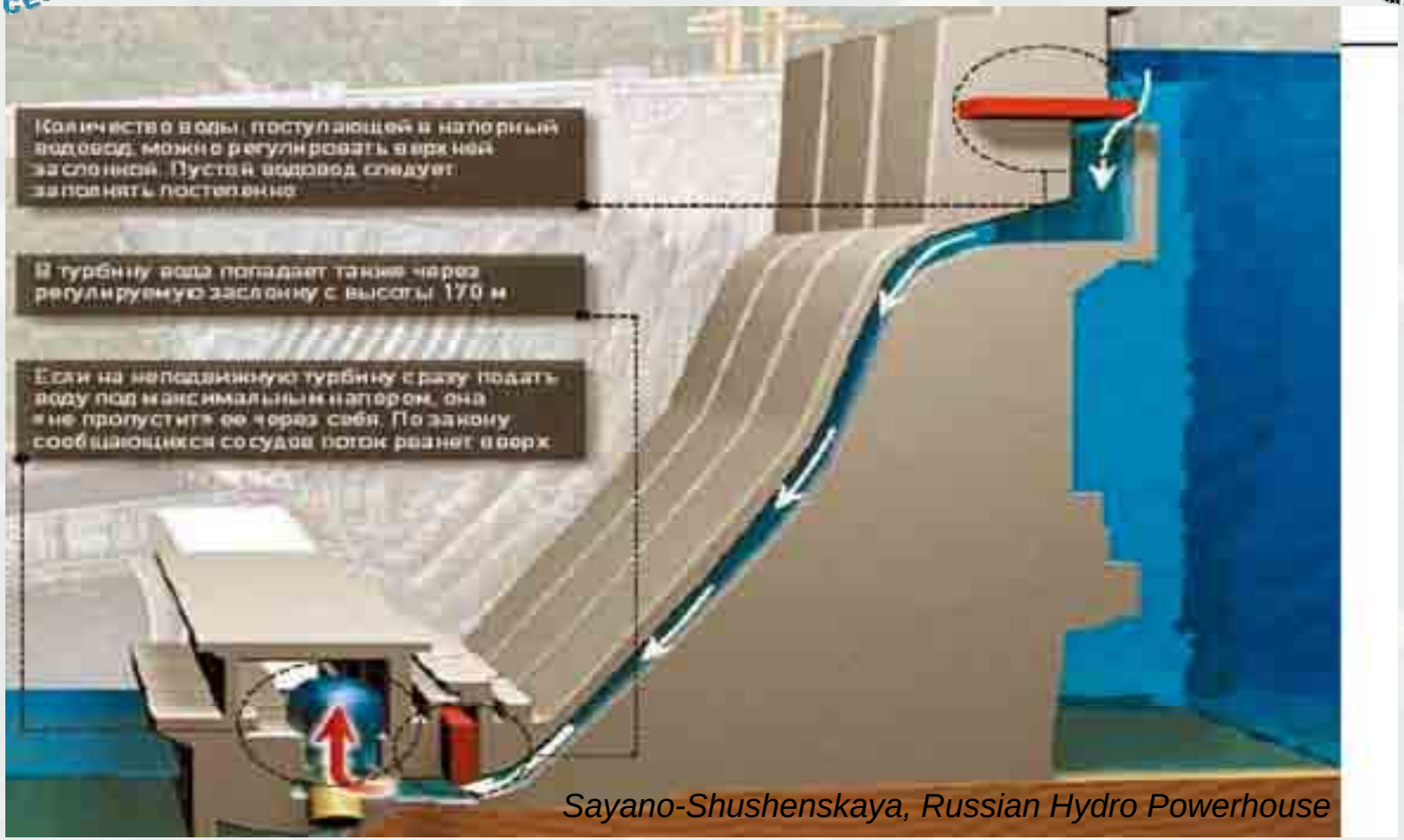
The net result is the unit was ejected from the turbine pit…

The Head Cover Studs Failed



Sayano-Shushenskaya, Russian Hydro Powerhouse

The unit weighs 2960 tons (US) and the rotor weight is 995 tons (US).



Sayano-Shushenskaya, Russian Hydro Powerhouse

There are reports that the Unit was ejected vertically 3 meter's (about 10 feet)……..

….resulting in this.

Sayano-Shushenskaya, Russian Hydro Powerhouse

Inside of the Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

The Damage

Sayano-Shushenskaya, Russian Hydro Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

Sayano-Shushenskaya, Russian Hydro Powerhouse

Aggravating Factors Before The Accident

- Severed communications from Bratsk powerhouse.
  - 17 August 1:20 am, fire at Bratsk powerhouse downstream of Sanyo. The ability of Bratsk to provide AGC and other ancillary services to the power grid operator lost.
- AGC is moved from Bratsk to Sanyo a high head plant.
- Design of the studs & no inspection requirements.
- No pretension on the studs.

Aggravating Factors Before The Accident, Cont'd

- New Governor controls on Units 2, 5 & 6.
- Worn out guide bearings contributed to higher vibration.
- Cavitation had contributed to vibration / unbalanced runner.

What Happened?

- The accident was primarily caused by the head cover studs failing.
  - **80 studs held the head cover down.**
  - **41 studs had fatigue cracks**
  - **2 studs were destroyed by tension**
  - **6 studs completely undamaged, leading to the conclusion that no nuts were present.**
- Average fatigue damaged area exceeded 65% of the total stud cross section.
- The cause of the failure is still being debated. Leading candidates are unit vibration, load rejection, or governor failure.

Contributing Factors

- Studs not prestressed—or perhaps inferior steel
- Failure to monitor Head Cover Stud Condition
- Failure to shut down upon increased vibration
- Corporate Culture stressing profit/operation at the expense of safety
- Inadequate vetting of new governors
- Accepting as ‘normal’ the operation of the machine outside design specifications

Could an Accident Like This Happen to the Corps?

YES

IT'S NOT ONLY SAYANO !!

THREE BREACHES IN PAST 20 YEARS

Manitoba Hydro Grand Rapids Unit 4

Unnamed European Plant

Sayano-Shushenskaya

THE BIG PICTURE LESSON

IT IS NOT: MONITOR THE HEADCOVER STUDS

IT IS: MONITOR WHATEVER CONTAINS THE DEADLY ENERGY

Recommendations to HQ USACE

- Inspect all turbine head cover studs and nuts.
- Verify that the emergency closure systems function at all plants and test the emergency closure gates under full unit flow.
- Verify all governor shut down and timing (wicket gate closure speeds).
- Review Emergency Plans and Procedures
- Maintain Staff Competency
- Inspect turbine runners for cracks.

Recommendations to HQ USACE

- Inspect head covers for structural integrity.
- Inspect penstocks for structural integrity.
- Develop vibration limits and install vibration monitoring systems.
- Re-examine the COE guidance on emergency gate closing time.
- Provide adequate back up power capability to maintain plant control.
- Assure that adequate engineering oversight is applied when major repair is performed or when energy containing components are disassembled or reassembled

QUESTIONS?