# Executive Summary

This presentation will address the following:

- Reported condition of the IPP generators

- Feasibility of increasing the power output of the IPP Generators
  - Review results of the November '01 Cursory Generator Uprate Study
  - Need for a Full Generator Uprate Study to address the challenging 1056 MVA @ 0.90 PF output requirement.
  - VAR and Power Factor Discussion

- Long-term reliability of the Generrex-CPS Excitation System
  - Excitation System Uprate and Modernization
  - GE Digital Excitation Systems for Retrofit Applications
  - Disabling the existing Generrex-CPS and installation new EX-2100

- Need for a comprehensive AC and DC Transmission System Study
  - Addition of a third generating unit at the IPP Station

- Generator Issues and Recommendations
  - GE Liquid Cooled Stator Rewind Technology

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Top Shelf Items - Top Check Please

U3 Inspection 2005

U2 2004 Pull Sided Inspection Jumper

Fall Out Sided Tests Look Below.

# *Reported Condition of the IPP Generators*

- The IPP generators are the largest two-pole core diameter machines ever built by GE. They were uniquely designed to meet IPP specs. No "similar-to" units. Unit 1 shipped in 1983. Unit 2 shipped in 1984.

- Global epoxy on both units. Both units experienced leaks (Unit 1 reported to be leaking at clip-to-strand, Unit 2 at the phase connection rings where bars enter dome). Both generators had failed Hit Skid testing last two times tested.

- Both generator fields experienced pole-to-pole jumper migration which had been repaired in the 90's. Field inspection on Unit 1 is planned in 2003. Need TIL-1292 inspection. Good operating history on both fields. No sensitivity to reactive load changes.

- Large base load units. 98% availability. 94% capacity factor.

- IPP may consider stator rewinds with excitation system retrofit (~2005). Cycle time critical. 30-days breaker to breaker.

- MVARs are important. IPP wants to restore 0.90 PF.

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*Generator Uprates*

# Generator Uprate Discussion

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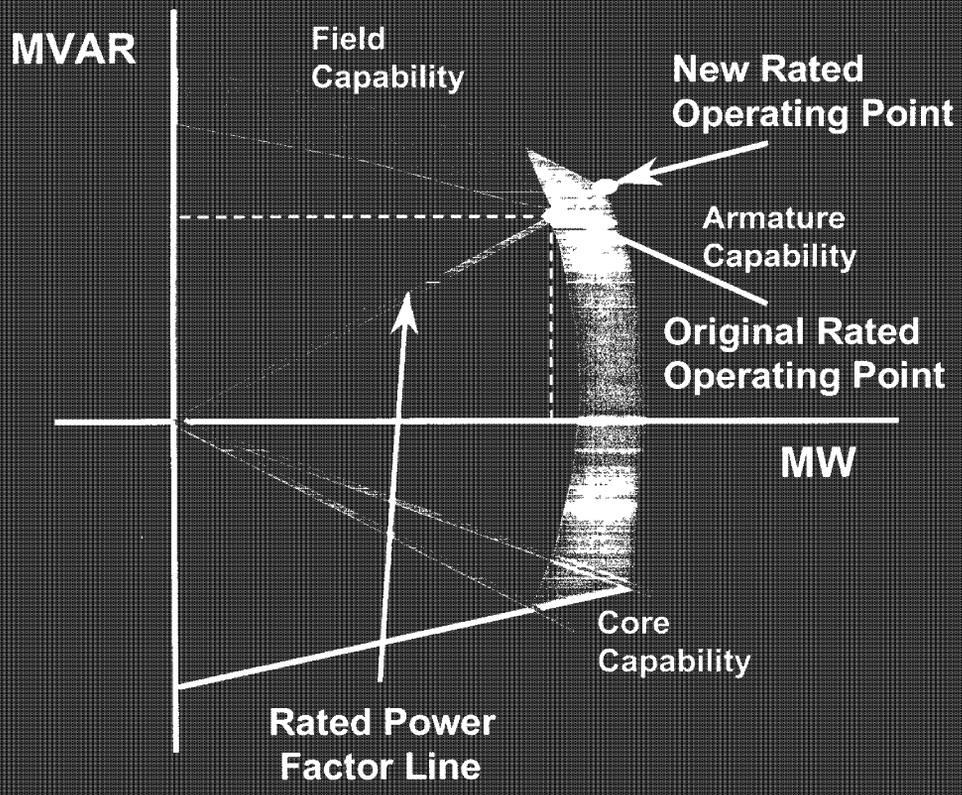
# *Feasibility of Uprating a Generator*

## Reactive Capability Curves




- The maximum generator performance is defined by the original rated operating point
- An uprate can provide a combination of more MVAR and MW as defined by the new rated operating point
- The ability to uprate a generator is dependent on the capability of:
  - –Field
  - –Armature
  - –Stator Core
  - –Generrex-CPS

**Uprates must consider the entire generator system**

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# November '01 Cursory Generator Uprate Study

## As Shipped Rating

- 991 MVA @ 0.90 PF
- (892 MW / 432 MVAR)
- IFFL = 5363 Amp DC

## Proposal 1

max limit

1001 MVA @ 0.90 PF

901 MW / 436 MVAR

IFFL = 5499 Amp DC

**Findings:**

Stator winding limiting at 1001 MVA

Exceeds capability of the field (IFFL)

→ Consider PF increase to 0.93
(931 MW / 368 MVAR)

## Proposal 2

Upgrade Stator Winding

1056 MVA @ 0.90 PF

950 MW / 460 MVAR

IFFL = 5748 Amp DC

**Findings:**

Exceeds the capability of the stator winding. Need to study the feasibility of a new redesigned stator winding.

Exceeds field capability (IFFL). Needs full evaluation of the field.

→ Consider PF increase to 0.96
(950 MW / 279 MVAR)

Exceeds capability of the Generrex-CPS. Consider replacing with EX-2100.

**IPP is considering operation at 950 MW and 0.90 PF per generator. This corresponds to a new generator rating of 1056 MVA and 0.90 PF.**

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Leading PF- Toughan System

# Generator Uprates - Hardware / Analytical

- The Generator is a System - Need to Look at all Components
  - *Armature Winding*
    - » *increased electromagnetic forces - bars and individual strands*
    - » *increased temperatures*
  - *Stator Core*
    - » *end core iron temperature*
    - » *end core iron flux density*
  - *Rotor*
    - » *Amp-turn capability of the existing winding (IFFL)*
    - » *Negative Sequence Current evaluation*
    - » *Increased temperatures*

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# Generator Uprates - Hardware / Analytical

- **Misc Generator Components Investigated**
  - *Main Hydrogen Coolers*
    - » *increased heat removal*
    - » *ventilation analysis of generator*
  - *Stator Water Cooling Skid*
    - » *increased flow and pressure*
    - » *increased heat removal*
  - *HV Bushings*
  - *Current Transformers*
  - *Other components, as needed*

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# *Full Generator Uprate Study*

- **The study will look at 1056 MVA at 0.90 PF, and will include the following:**
  - » **Stator core magnetic flux analysis**
  - » **Armature winding electromagnetic and thermal analysis**
  - » **Rotor field winding electromagnetic and thermal analysis**
  - » **Main generator hydrogen coolers**
  - » **High voltage bushings**
  - » **Stator water cooling system**
  - » **Generator rotor torsional mechanical analysis**
  - » **Main generator ventilation analysis**
  - » **Seal oil system**
  - » **Hydrogen control system**
  - » **Collector rings, Brush rigging assembly**

NOTES:

- Generator components will be analyzed in "as new" condition.
- Applicable generator TILs will be identified and recommended.
- Per our records, all generator-related equipment appears to be GE. Non-GE equipment cannot usually be uprated.

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*Generator Uprates*

# VAR & Power Factor Discussion

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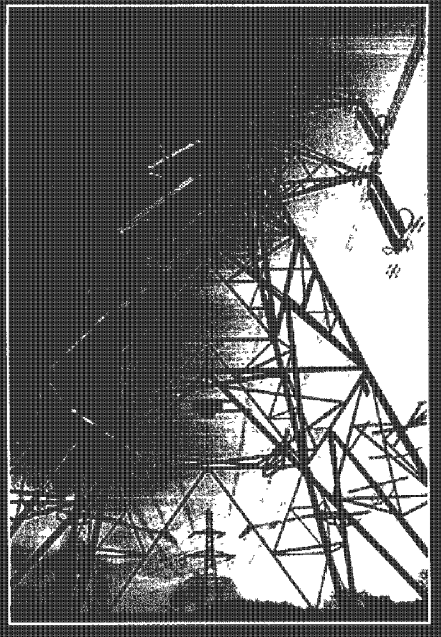
# Watts & VARS - Power Factor

## Two Important Commodities Produced by a Turbine Generator Unit



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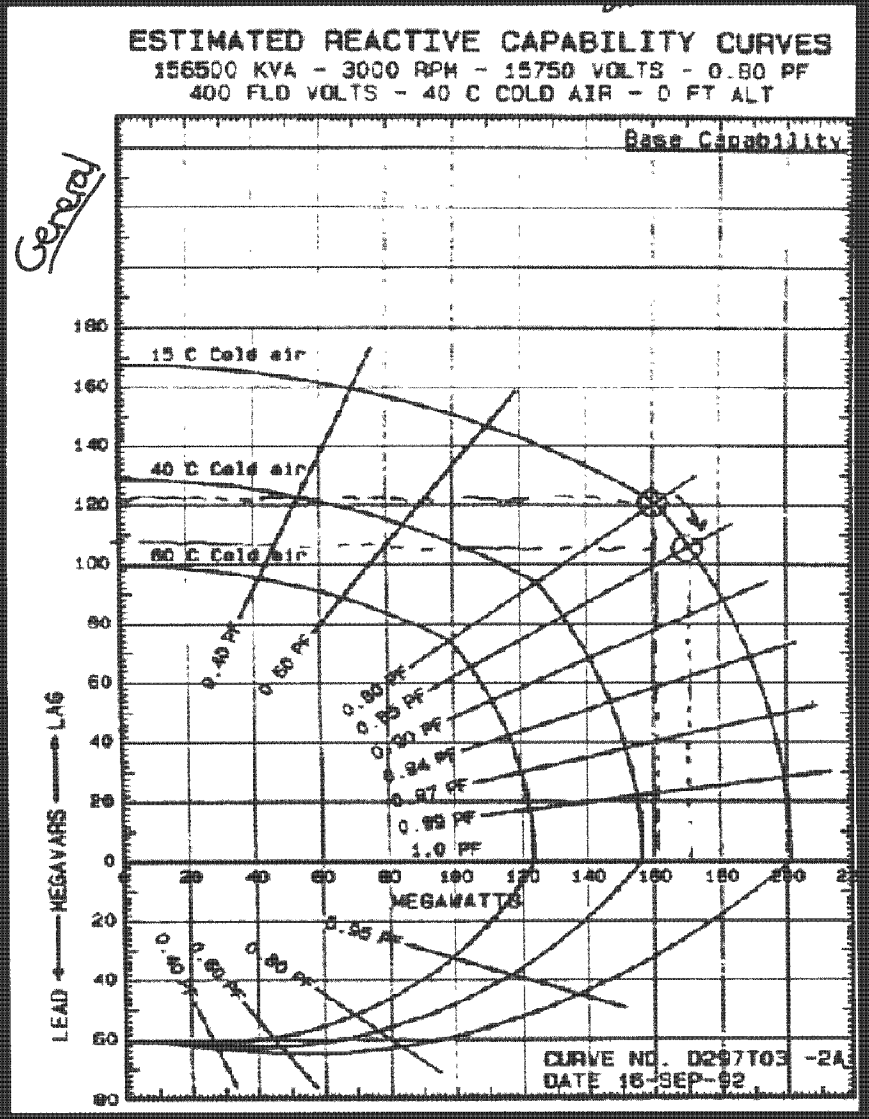
# Typical Generator Reactive Capability Curve




Raising the power factor means Watts for VARs trade off

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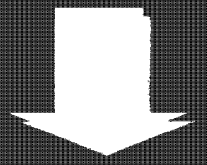
# *If You Need VARs*

- Upgrade and Uprate the Generator and the Excitation System



  - More pressure from NERC Guidelines for 0.9 pf and testing due to several years of brownouts and blackouts
  - GE Power Systems Energy Consulting (PSEC) actively involved to help you quantify your actual VAR need and capability
  - PSEC can do testing and analytical studies:
    - » 125+ NERC system modeling tests (excitation controls, T-G models)
    - » Comparison study of VAR alternatives

  VARS are not "imaginary" – becoming increasingly real to power system operators

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*Generator Uprates*

# Excitation System Discussion

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# *Excitation System Upgrade*

**IPP is concerned with the long-term reliability of the existing Generrex-CPS system**

**The EX-2100 excitation system is today's digital replacement for the Generrex-CPS system.**

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HV-DC transmission / Exciter very high response

IP12_011574

# Evaluation of Excitation System Performance

- Present excitation system:
  - High response, high initial response (HIR)
  - Compound power source
- Performance of the excitation system is also dependent on characteristics of the power system
- GE PSEC (Power Systems Energy Consulting) has performed extensive evaluation of the IPP excitation system and power system
- Evaluation of the busfed EX2100 excitation system would be an important part of overall uprate & upgrade evaluation
  - Evaluation of busfed HIR system and determination of acceptable response
  - Impact of AC and DC transmission systems at IPP

**PSEC Analytical Tools Allow the Study of Generator, Excitation System, and Power System Interactions**

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# Unique Characteristics of IPP Plant

- Generator load is dominated by HVDC converter station
  - Voltage and swing characteristics are significantly different from typical plants tied only to ac transmission lines
- Ac ties from Intermountain to Utah and Nevada are weak
  - Maintaining stability may depend on special control actions, such as HVDC power modulation and/or generator tripping
- Existing exciter and PSS are coordinated with these unique system characteristics
  - 6-response exciter sized to meet WSCC stability requirement
  - PSS tuned to damp 0.7 Hz inter-area mode

**New exciter and PSS must be designed to address all these issues, given the new ratings and system operating conditions**

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modulation function / power system stabilizer

NERC criteria

WSCC system - stability studies · modeling ·
re-evaluate w/ U3 or uprate

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# *Implications of New 3rd Unit*

- Maintaining stability will be a bigger challenge
  - Plant will have 50% more accelerating power during faults
- When all units are running, 400-500 MW will need to go to Utah
  - Less margin to absorb power swings across ties to Utah
- Meeting WSCC stability criteria will likely involve a combination of
  - HVDC control functions (e.g.., power modulation)
  - Excitation system performance (rating and PSS)
  - Remedial action scheme (e.g.., generator tripping for certain severe system disturbances)

**System studies by GE-PSEC can help develop an overall plant design that meets all necessary requirements**

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Kurt O'Brien

IP12_011578

GE Power Systems

# GE Digital Excitation Systems For Retrofit Applications

June 18, 2002

IP12_011579

LouBrown

# *Background*

**Many aging excitation control systems are limiting plant performance:**

- More frequent repairs leading to forced outages and production interruptions
- Spare parts are becoming scarce
- Limited ability to interface with newer plant DCS and Enterprise level systems.
- Cannot be expanded to accommodate new requirements (e.g., I/O, memory, space etc.)

**Customers need excitation solutions**

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New EX2100 excitation - digital

GE Energy Services &
GE Industrial Systems

# IPP Excitation System Uprate & Modernization

- Present Excitation System:
  - GENERREX-CPS (compound power source)
  - Hydrogen cooled transformers, reactors, generator neutral tie in generator dome; P bars adjacent to stator winding
  - Water cooled rectifiers, analog controls located next to generator
- Excitation System Uprate & Modernization
  - GENERREX-CPS controls and rectifiers cannot be used with a busfed excitation system
  - Transformers / reactors are at max capability
  - Busfed EX2100 excitation system can support uprate goals
  - Busfed EX2100 excitation system represents the modern offering for large multi-bridge systems
  - EX2100 provides the significant advantages of a digital control system

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If upgrade generator. H2O P bars How to connect to excitation System

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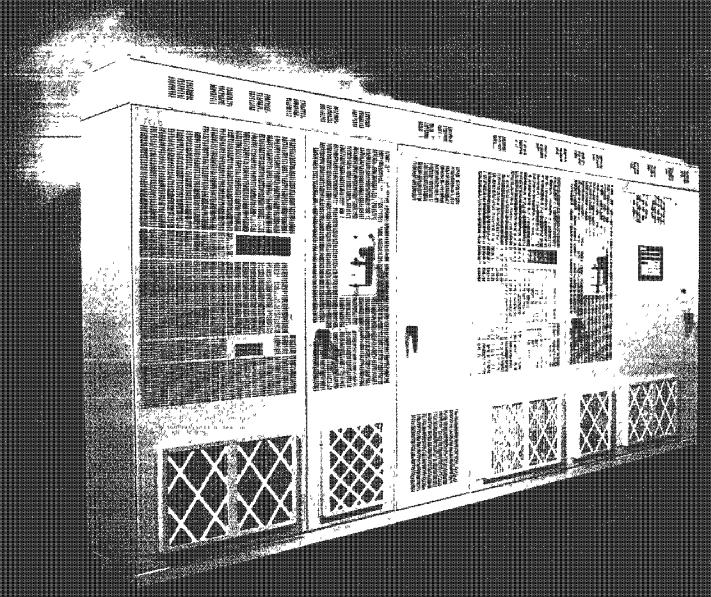
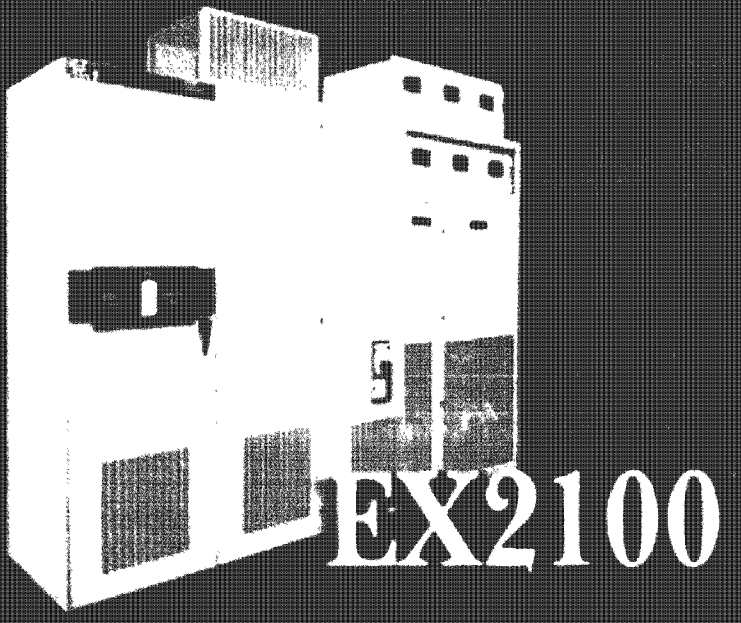
# *Excitation Control Systems*

**GE digital controls provide maximum reliability combined with flexible design and ease of operations**



**EX2000™ Excitation System***

*Over 1000 systems in operation worldwide.




**EX2100™ Excitation System**

## Proven designs - evolving to meet customer needs

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heat pipe cooling technology
heat pipe / plate / fluid

# *EX2100 Benefits*

## Reliability

- Triple Modular Redundant (TMR) features for highest running reliability
  - Allows on-line testing and automatic transfers between main and back-up units
- Patented field ground detector
  - Accurately determines location and magnitude of ac/dc grounds
- Power System Stabilizer reduces system blackouts
- On-line repair for redundant control options
  - Includes on-line repairs for fan units

**Minimize forced outages and downtime**

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# *EX2100 Benefits*

## Easy to Operate

- Accessibility designed throughout system
  - Bottom and top entry for controls and power
  - Pull-out fan drawers for easy change-out
- Fully integrates to higher level control systems
  - Mark VI Turbine Control & ICS
  - Serial or Ethernet Modbus RTU
- User-friendly interfaces
  - Local keypads
  - Human-Machine Interface (HMI)
    - » Mark VI HMI
    - » Control Operator Interface (COI)
  - GE Control System Toolbox
  - Test and setup wizards guide operators through start-up, operations and diagnostics

**Minimizes training and increases productivity**

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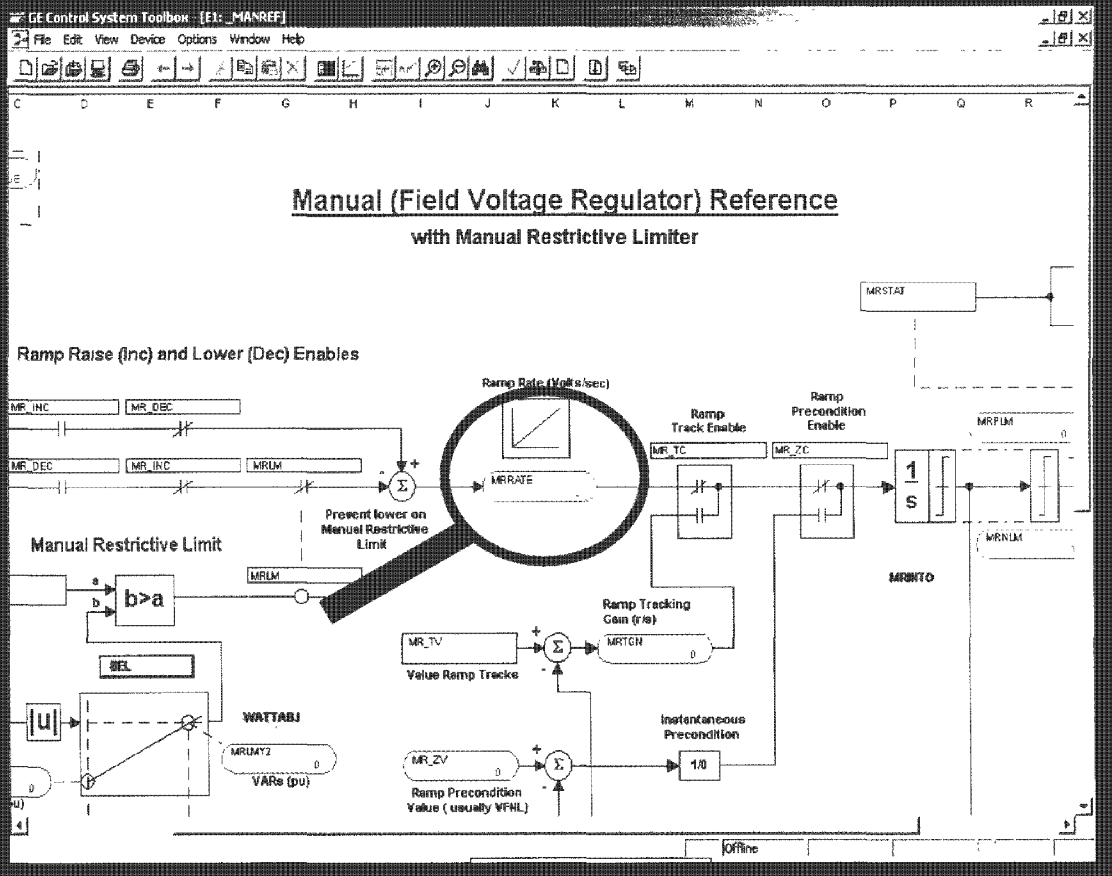
# Software Maintenance Tools

**Software maintenance tools allow users to change parameters and view data to meet their specific needs.**




## Features

- System Block Diagrams
  - Live signals viewing
  - Parameter changes

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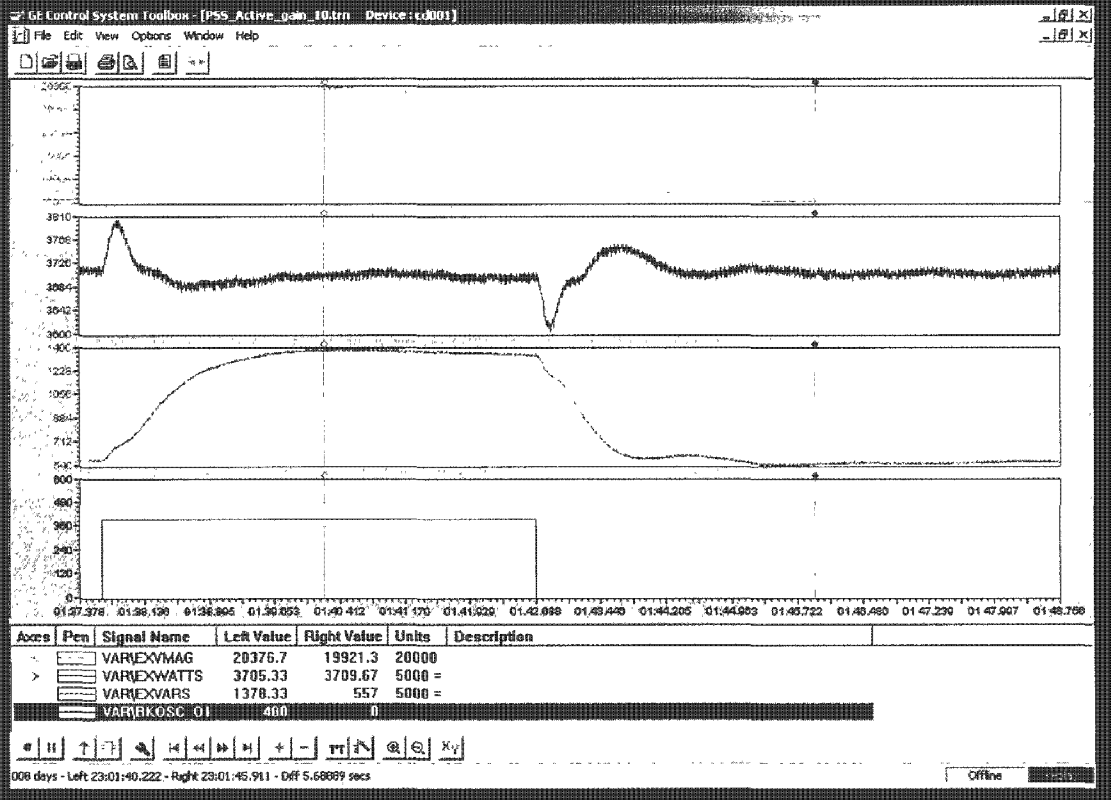
# *Software Maintenance Tools*

**Software maintenance tools allow users to change parameters and view data to meet their specific needs.**




## Features

- Trending
  - High speed buffered
  - Live Trending

**Flexible to meet all engineering and maintenance needs**

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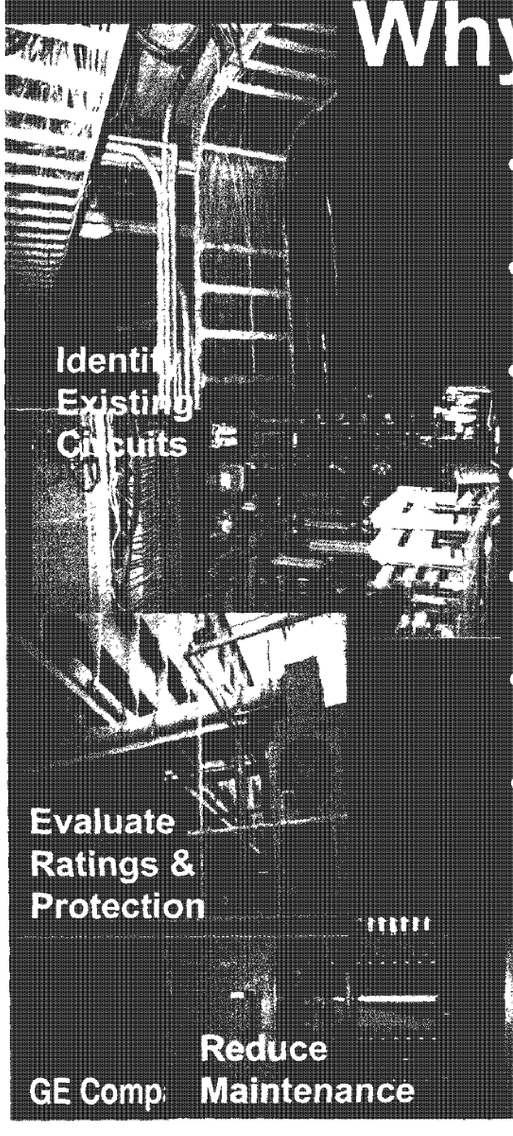
# Summary

## Why GE?

- State of the Art Controls
- System Life Extension
- Single Point Responsibility
- Reduced Project Cycle Time
- Increased System Reliability
- Improved Staff Productivity
- Competitive Installed Cost

*"The Power of the Package"*



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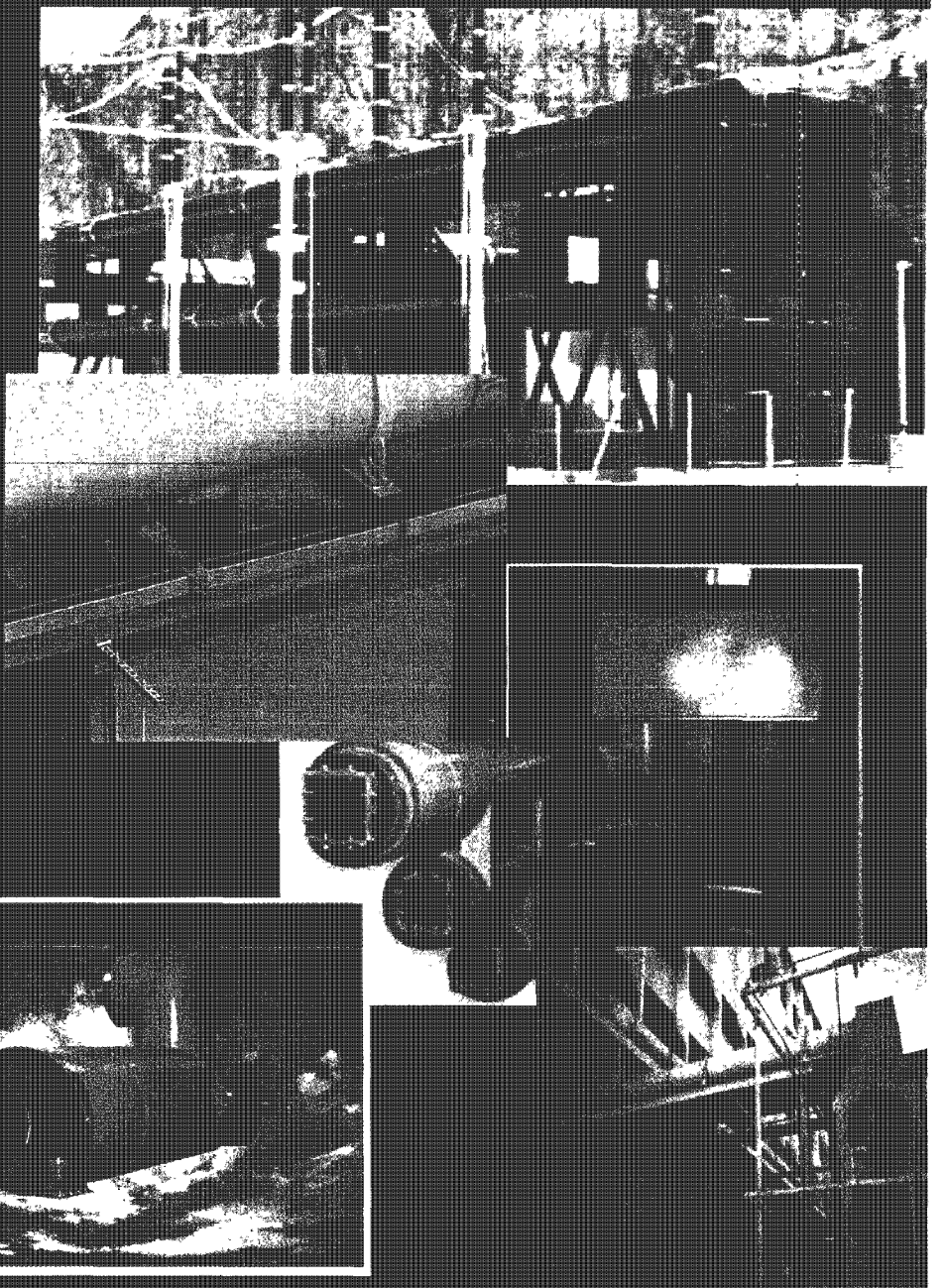
# Excitation Retrofits

## Iso-phase Bus

***Isolated Phase Bus*** (Iso-phase or IPB) is used extensively in power plants to convey current from the generator terminals to the 'GSU' transformer. This bus duct is usually 18KV to 27KV, & up to 25000 amps. These systems are normally totally enclosed.



### Excitation Retrofit Impact?

- High current exciters (Alterrex, Generrex, Althyrex, etc) will often require "tapping" IPB for high current AC source.
- IPB tap requires precise engineering and certified welding which drive high cost.
- IPB drives special consideration for PPT: IPB connections, primary protection concerns, increased size and cost.
- IPB tap drives installation cycle and outage duration.
- Cost per foot requires optimum equipment positioning.

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# Excitation Retrofits

The GE Engineering Design Package is the most comprehensive installation and documentation package available in the market. A differentiator…

Dedicated COE of electrical engineers and designers specializing in excitation and turbine control packages.

Detailed interface transition from existing system to new hardware.

Multi-discipline support for all civil, mechanical, and structural scopes.

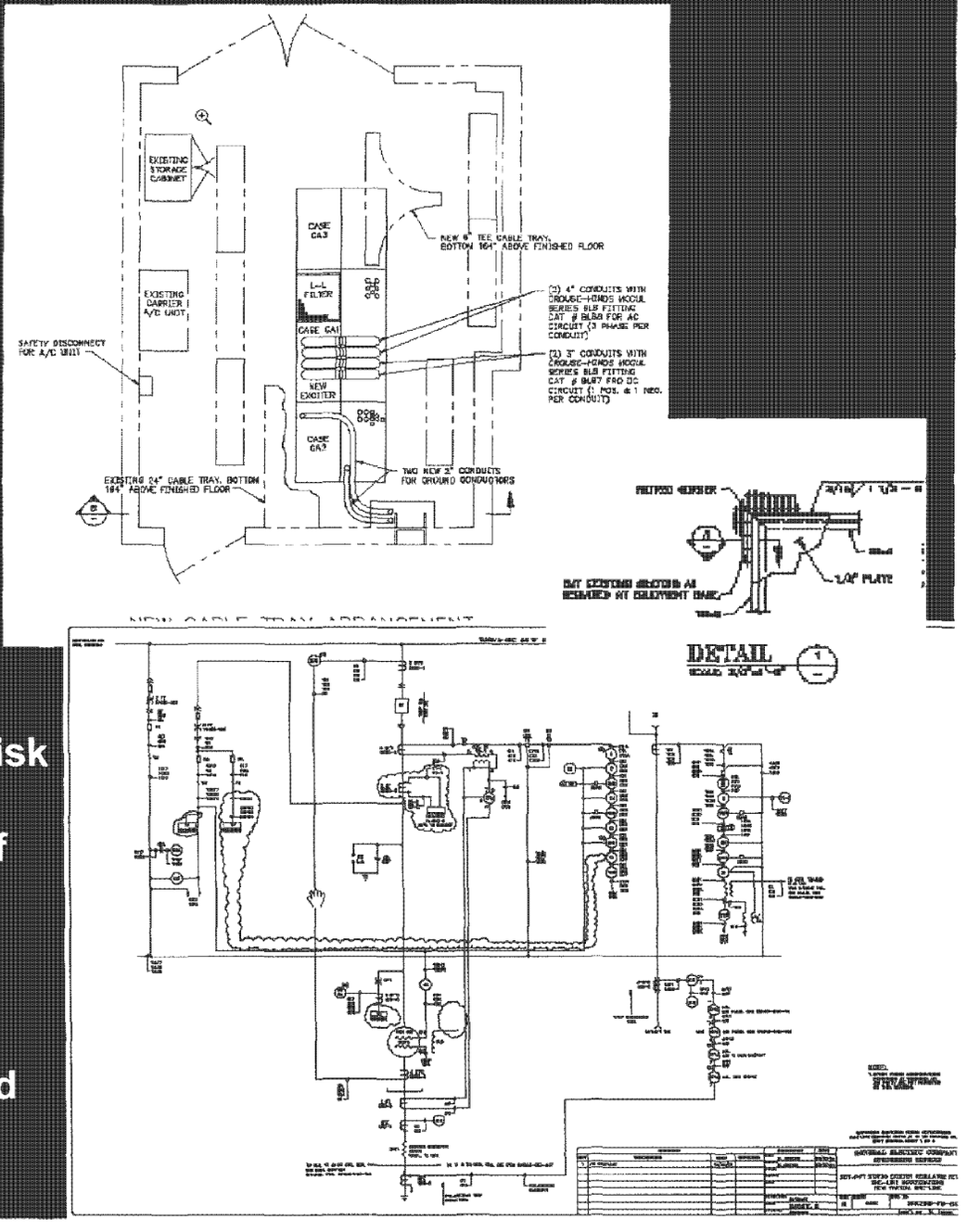
Reduced installation outage duration, and risk

Reduced installed cost due to elimination of contingencies and estimating error

Reduced site staff loading

Tiered offerings to best match customer and project need

## Engineering Design Packages

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# GENERATOR MODIFICATIONS

GENERREX-CPS to
EX2100 Busfed Static Excitation System

- GENERREX reactors and transformers in the dome would be eliminated (or disabled) in favor of a 3 phase excitation transformer placed outside the generator (normally on the mezzanine level near the iso-phase busduct)
- The P bars in the generator stator would be eliminated as part of a stator rewind (P connection rings would be disabled)
- The main generator neutral will be located in the dome as it is now – mechanical and ventilation evaluation would be required.

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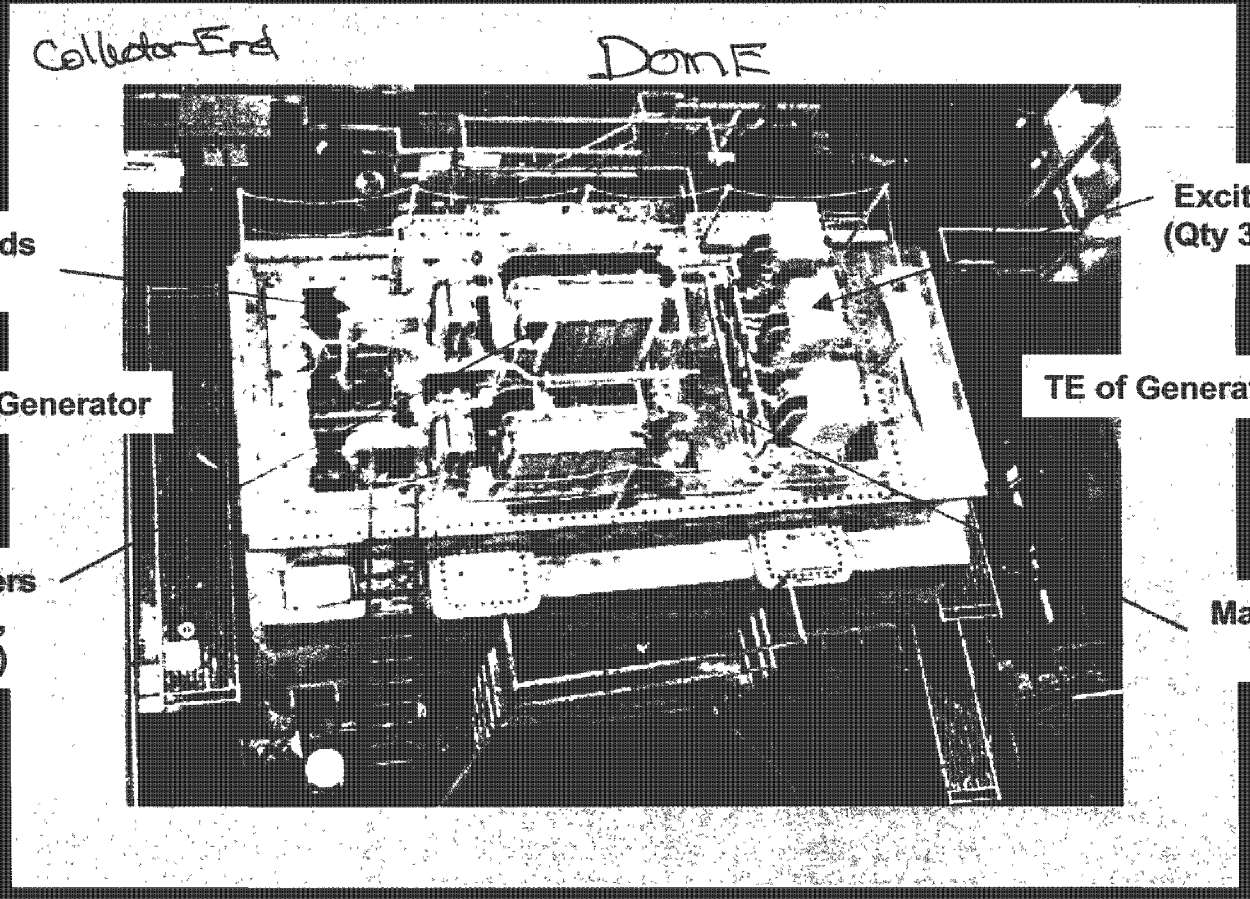
# TYPICAL GENERREX- CPS EXCITATION SYSTEM

*GENERREX COMPONENTS IN THE GENERATOR DOME*
*Top View of Generator with Dome Off*

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*IPP Generators*

# Generator Issues and Recommendations

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PDA - Patient data storage

mm. dann

# Generator Issues and Recommendations

–

» Test and Inspect per GEK 103566 - “Creating an Effective Maintenance Program”

» Update Maintenance History per Outstanding TILs including:

- **TIL 1098 (Inspection of Generators with Water Cooled Stator Windings)**
- **TIL 1197 (Liquid Cooled Stator Bar Abrasion)**
- See **GER 3751A** “Understanding, Diagnosing, and Repairing Leaks in Water-cooled Generator Stator Windings”

» Add On Line Diagnostics (SLMS and PDA)

–

- Windings have a finite life
- Life extension & increased reliability
- Increased efficiency
- Increased output
- Longer inspection intervals
- Compliments Uprates to the Steam Turbine

–

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Stacking - Station Bars

# Generator Issues and Recommendations

- Leaks (TIL 1098) and Bar Abrasion (TIL 1197) are two key reliability issues for large water cooled generators.
- A wet bar will eventually cause a winding ground. A wet bar can only be eliminated by replacing the bar(s).
  - Risk of a Forced Outage:

    Probability of an in-service failure is minimized if testing recommendations are followed. However, consequences of such a failure are extreme.
  - Risk of Extending a Planned Outage:

    Finding a wet bar during a planned outage can result in a significant outage extension if contingency plans are not put in place. Significant lead time is required to manufacture replacement bars.

- Wet bars due to leaks have resulted in megger and hipot testing failures and at least one in-service failure.
- At least 5 forced outages or unanticipated bar replacements have resulted from bar abrasion.
- 65 full rewinds have been performed by GE through 2001. GE is the industry leader in high quality, short cycle rewinds.

- The generators are highly rated 2 pole machines with high relatively bar forces. These machines would be particularly susceptible to bar abrasion if slot clearances have developed over time and if oil has leaked into the generator at some point.
- The generators have both seen about 20 years of service – the windings are likely candidates for refurbishment.

- Perform testing and inspection per TIL 1098 and GEK 103566.
- Install SLMS (Stator Leak Monitoring System) on the generators if not already in-place
- Establish contingency and maintenance plans to avoid unplanned extension of maintenance or forced outages:
  - Stocking of spare bars and long shelf life materials
  - Proactive stator rewind
- References:
  - GEK 103566 – Creating an Effective Maintenance Program
  - TIL 1098 - Inspection of Generators with Water Cooled Stator Windings
  - TIL 1197 - Liquid Cooled Stator Bar Abrasion
  - GER 3751A, "Understanding, Diagnosing, and Repairing Leaks in Water-Cooled Generator Stator Windings"

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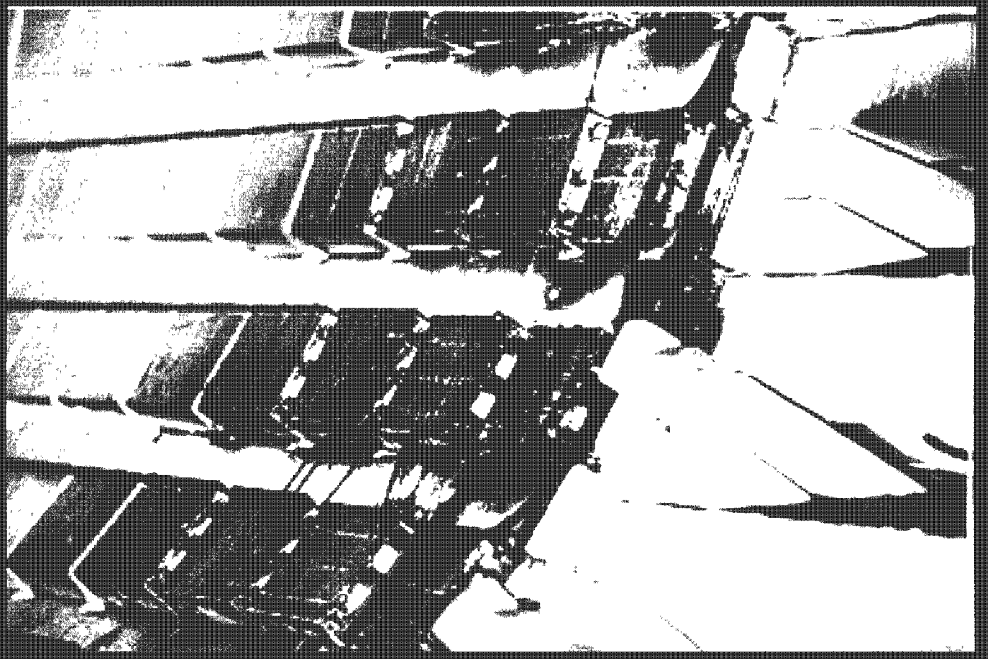
# Stator Bar Abrasion -- TIL 1197

- Since 1995, at least 5 forced outages or unanticipated extensions of maintenance outages have resulted from bar abrasion.
- Abrasion requires that a radial clearance has developed in the slot.
- Bar abrasion is generally linked with the presence of oil in the generator.
- Oil compromises the ability of the side ripple springs to restrain radial motion of the bars



**Early Detection Can Avoid Winding Failures**

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hydrogen seal oil any leaks cause misting which causes greasing of bars

copy - please return

# *Leak Origination Sites in Liquid Cooled Stator Windings*

***Not only*** ...

- Clips, Such as Crevice Corrosion ....

***But Also*** ...

- Copper Tubing, Piping, Connections, Elbows, Fittings, Sleeve Joints, Tube Extensions, Connection Sleeves
- Teflon™ Hoses and Fittings
- Inlet / Outlet Headers, Header Nipples
- Connection Rings
- Liquid Cooled HV Bushings and Connections
- "P" Bar Liquid Connections and Hoses

- See GER 3751A, "Understanding, Diagnosing, and Repairing Leaks in Water-Cooled Generator Stator Windings

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# *Elimination of Leaks at the Clip to Strand Braze*

***Extensive Development and Investment . . .***

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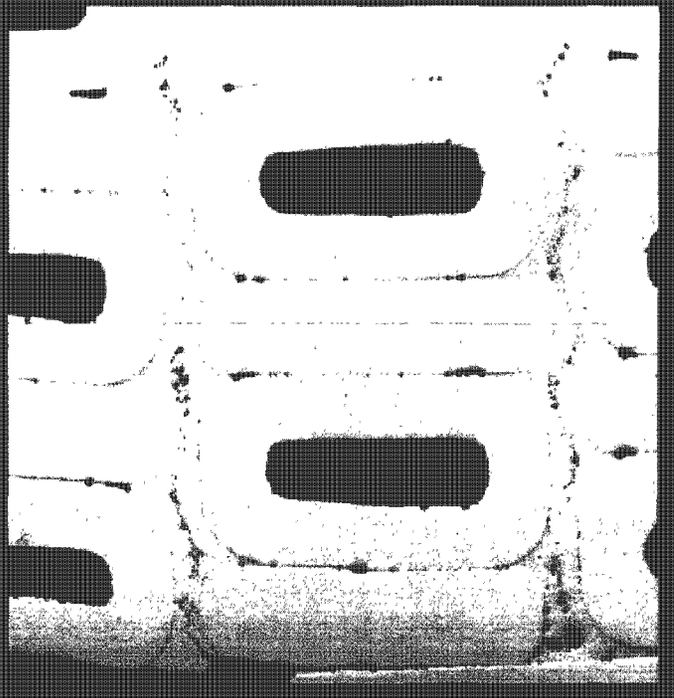
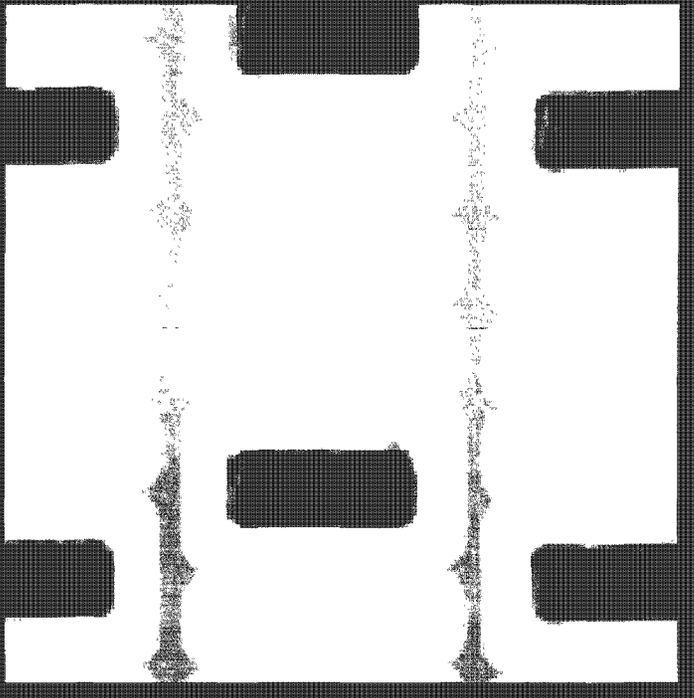
# *Improvement in Braze Alloy Material*



Foam Metal Braze Alloy
With Typical Porosity
(1970-1985 vintage)



Sintered Composite Braze Alloy
(Current Design)

Progression from Foam Metal to Sintered Composite Braze Alloy;
Increases void free braze length

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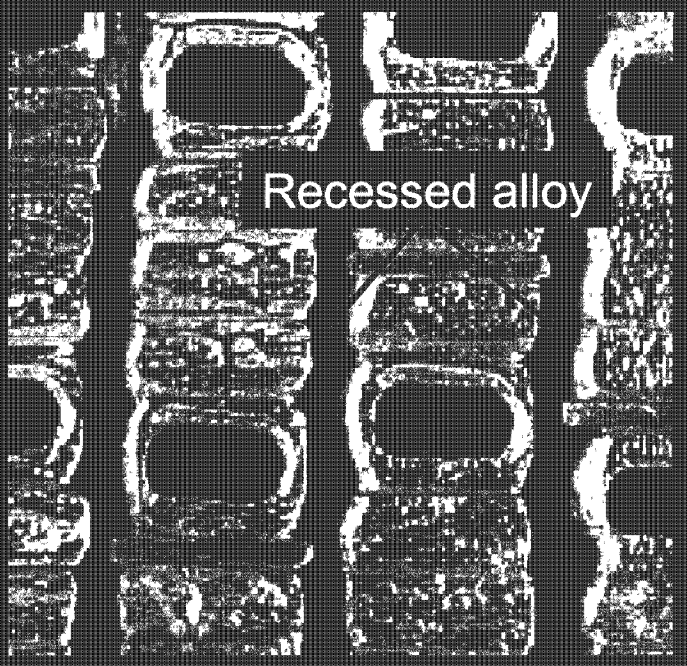
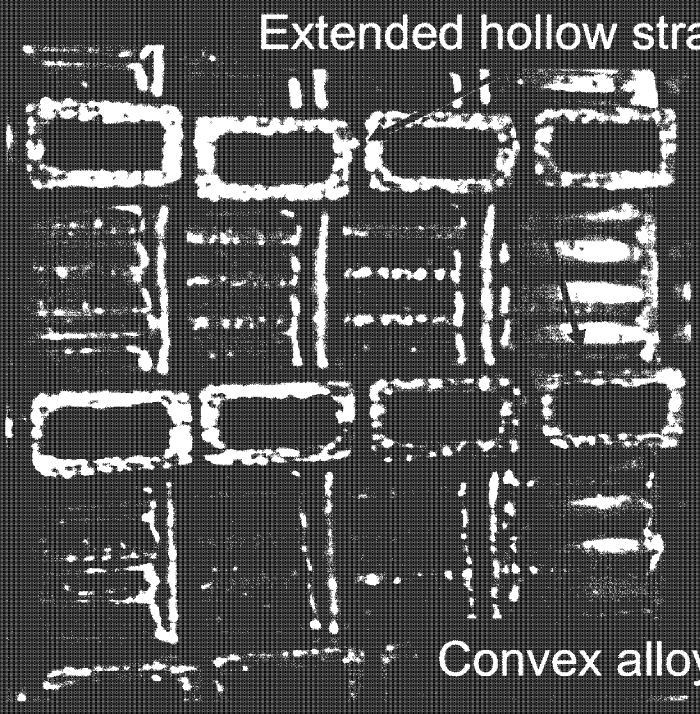
# Braze Improvement Results




Pre-1997 Vintage - Recessed Alloy

Current Process Manufactured Bar

**Current Process Bar is Robust:**
**Free of deep surface pits, Void free braze length maximized,**
**Excellent wetting, Oxidation minimized**

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# *Braze Improvements*

Significant braze process changes have been implemented including:

- Elimination of copper foam metal (1986)
- Sintered composite braze alloy to control internal voids (1986)
- Flush braze to eliminate deep surface pits (1997)
- 25% Increase in Braze Joint Length to 1.25" (1997)
- Induction cleaning of strands for improved wetting (1998)
- Improved induction brazing with computer temperature control (1999)
- Hollow strands extended beyond solid strands to eliminate plugging of hollow strands with braze alloy (2002)
- Use of forming gas for additional surface oxide reduction and reduced porosity (2002)

<u>Major Investments in New Product Introduction Programs and Modern Brazing Equipment and Processes</u>

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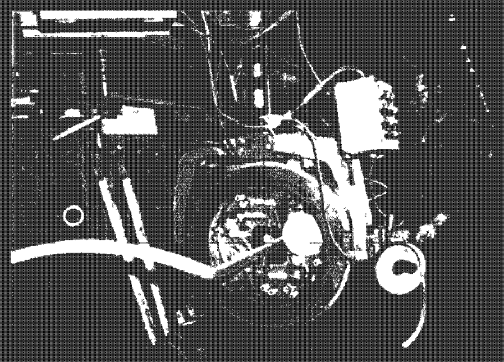
# Generator Stator Rewind Advances

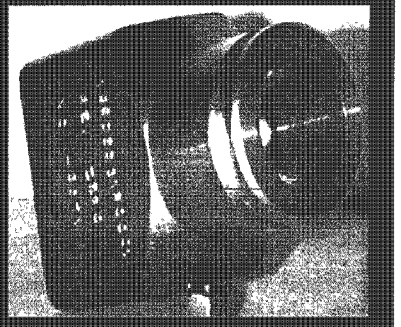
## Micapal II Insulation System

- MicapalTMII Insulation System Has Performed Flawlessly Since Introduction in 1975
- Constant Development and Process Control Has Maintained High Quality



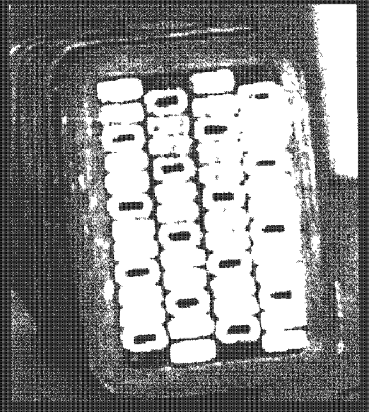
## Robust Stator Bar Clip-Strand Package

- New induction braze process for porosity control & corrosion resistance
- New induction cleaning process to eliminate rework
- Clip conversion to robust "Bottle Clip" design



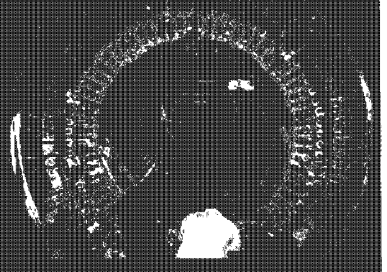
## Improved Electromagnetic Design

- Increase Roebel transposition for improved efficiency
- Optimize ratio of hollow vs solid strand package for improved efficiency



## Stator Rewind Process Quality

- Winding removal tooling shortens cycle w/less damage risk
- Rewedging tooling for consistent force control & short cycle
- Self-tightening slot support system for long term reliability



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IP12_011605

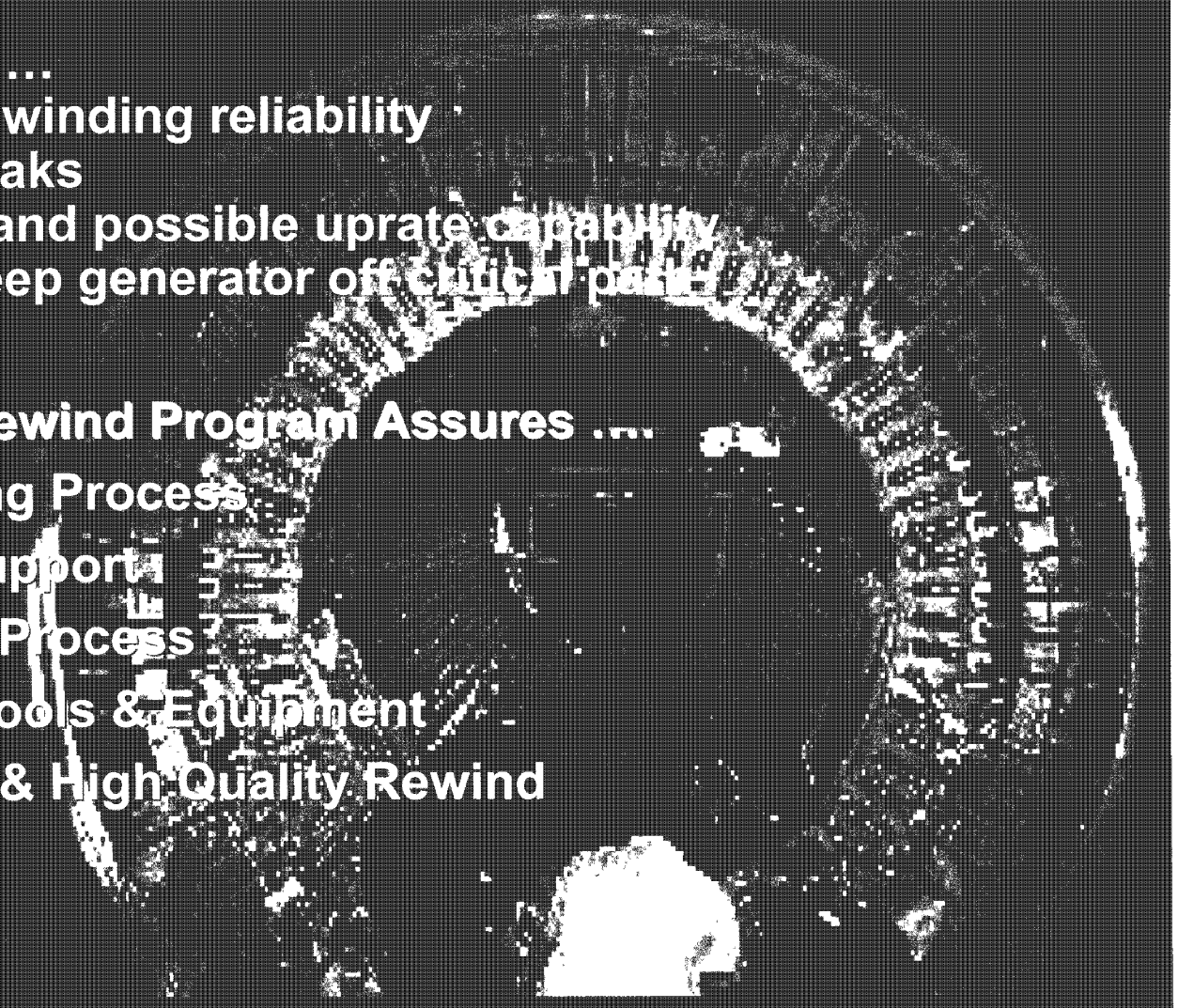
# Liquid Cooled Stator Rewind

A Complete Stator Rewind ...

- Restores highest stator winding reliability
- Addresses stator bar leaks
- Provides life extension and possible uprate capability
- Short cycle rewind to keep generator off critical path

GE Liquid Cooled Stator Rewind Program Assures ...

- Pre- Planning/Scheduling Process
- On-site Project Team Support
- Training & Certification Process
- Materials, Specialized Tools & Equipment
- Design for Short Cycle & High Quality Rewind
- Experience



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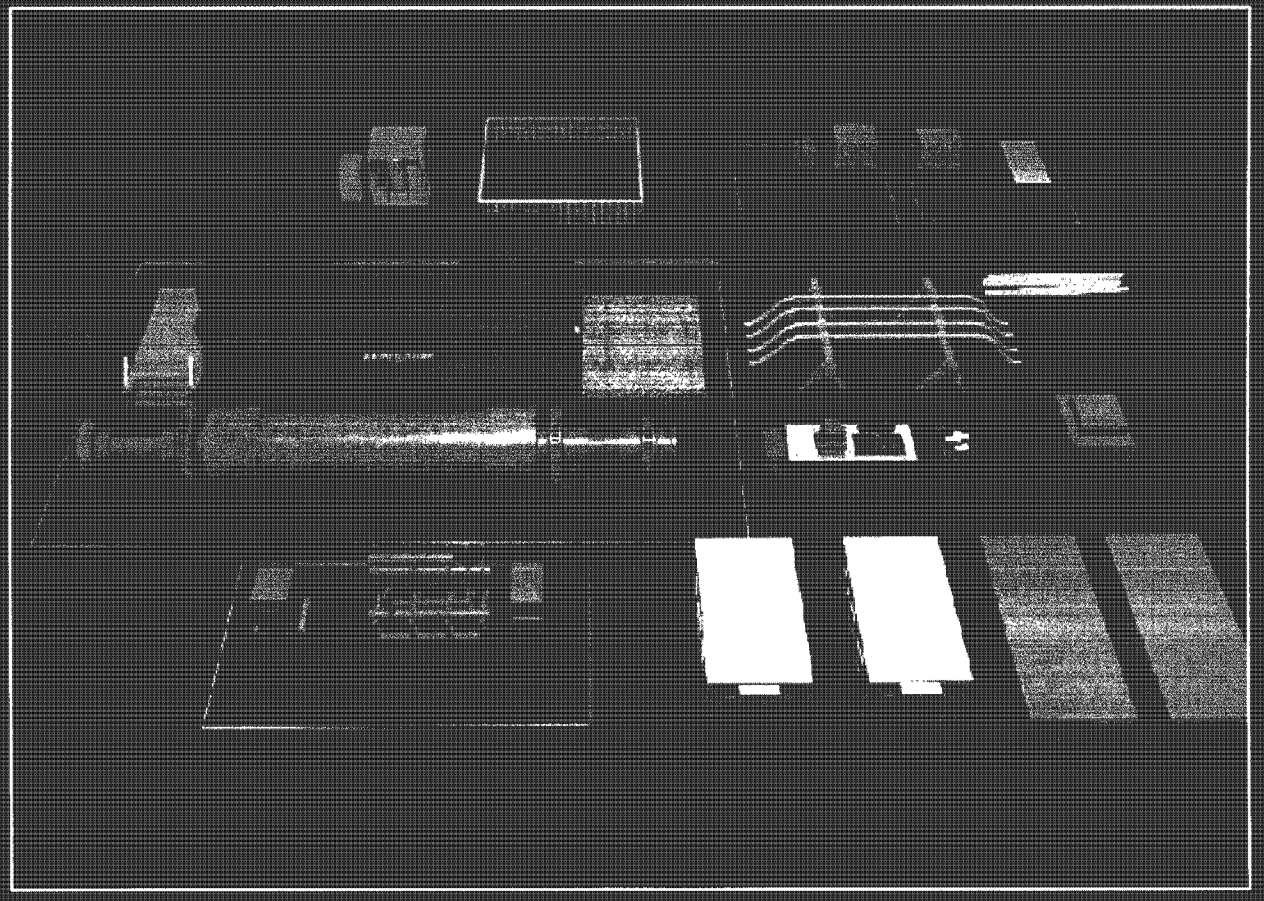
# *Staging & Laydown Logistics*



**One of Many Developments and Pre-Planning Activities that Deliver High Quality, Short Cycle Rewinds**

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need GEK 1098
GER 1071 ~~rB~~ rA updated
updated charts + statistical info

IP12_011608

Technical
GEn presentation

16 weeks

Need in depth evaluation + modeling

Uprate Study generator

Uprate Study - transmission
system issues

Excitation - upgate ~~or~~ replacement

U2 2 hydrogen - oil incidents
U1 ok

Re-wedging

~~Rewedge~~

Rewind 20 days

Where is leak? conduct hydraulic testing
connection ring
from P connection to Neutral connection (in dome)

IP12_011609

# *Summary of Reliability Issues on Water Cooled Generators*

- 
- **Maintenance strategies require pre-planning**
  - **Test & Inspection is critical to condition based maintenance planning**
  - **MAGIC In-Situ Inspection & GEK 103566 (Generator Maintenance)**
- **GE is the industry leader**
  - **Design and manufacturing experience**
  - **Testing and repair experience**
  - **Options to suit your goals**
  - **Demonstrated capability and reliability**
  - **The best value**
- **Remember to address other key generator reliability issues such as:**
  - **TIL 965 - Field Winding Copper Dusting**
  - **TIL 1292 - Rotor Tooth Cracking**

**Optimum Strategies Require Joint Effort**

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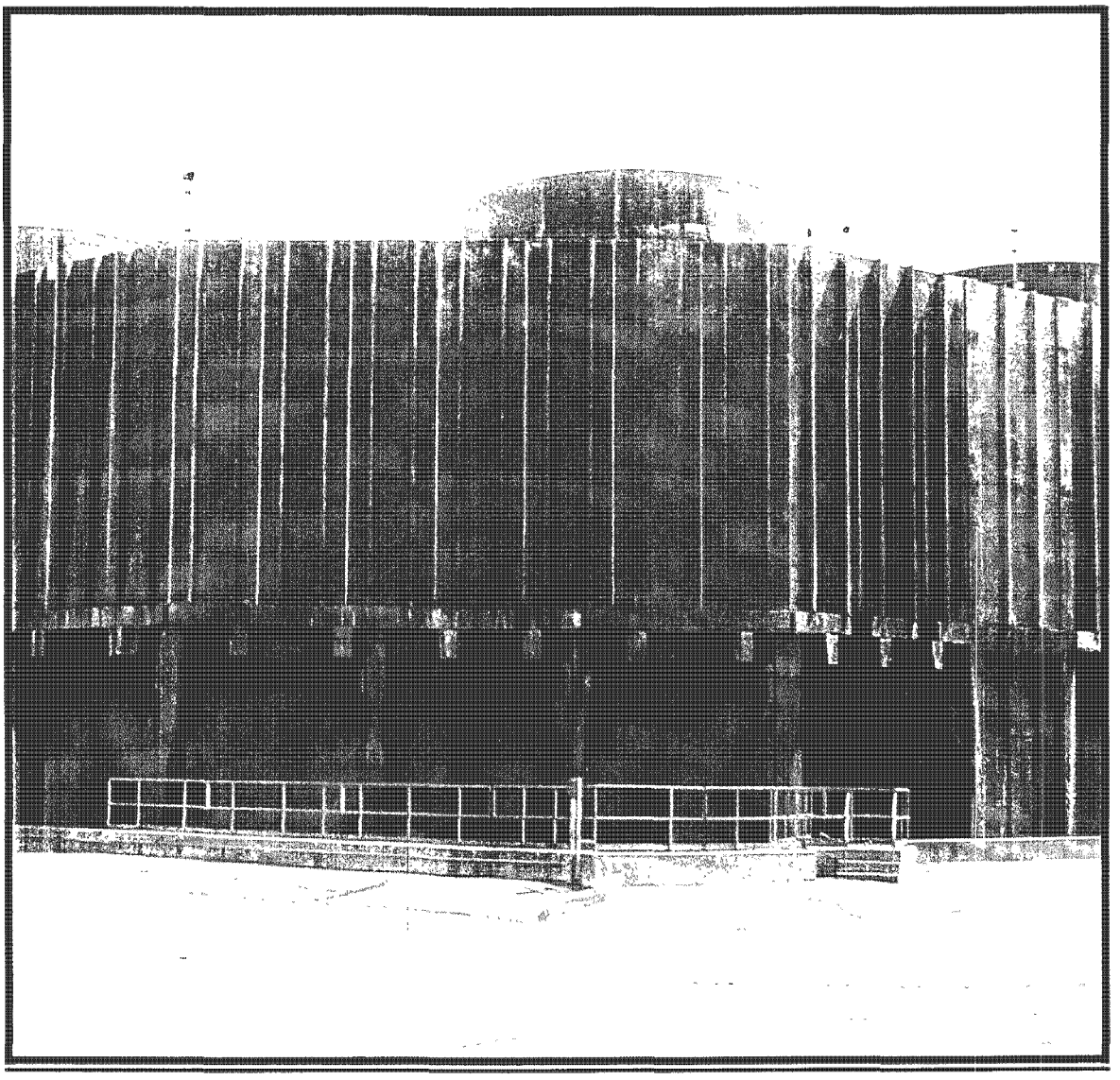
Restruction Corporation

# Report of Condition Assessment IPP-Delta Utah

## Cooling Tower Structural Components



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