CONDENSATION INDUCED WATER HAMMER

RISKS AND ISSUES ASSOCIATED WITH SAGD OPERATIONS

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OUTLINE

• CONDENSATION INDUCED WATER HAMMER (CIWH) – EXPLANATION
• STEAM ASSISTED GRAVITY DRAINAGE (SAGD) OPERATIONS – OVERVIEW
• RISKS OF CIWH IN SAGD FACILITIES
• MANAGING THE RISKS
CONDENSATION INDUCED WATER HAMMER
## WHAT IS CIWH

### CIWH

- CAUSED BY COLLAPSE OF STEAM BUBBLE
- REQUIRES SUB-COOLED CONDENSATE (> 36 F) TO INTERACT WITH STEAM
- MAXIMUM IMPACT PRESSURE CAN RUPTURE PIPING (JOUKOWSKY EQUATION – ρc²)

### SLUG FLOW

- CAUSED BY ACCELERATION OF WATER SLUGS DOWN A PIPE
- IMPACT PRESSURE BASED ON SPEED OF TRANSPORT FLUID (ρv²)
- PIPE MAY MOVE, NOT ENOUGH PRESSURE TO BREAK
1. Steam is allowed to flow over an accumulation of cooled condensate.

2. The hot steam collapses on contact with the subcooled condensate – this draws more steam into the line.

3. Enough flow occurs to form a wave in the liquid condensate that contacts the top of the pipe, isolating a pocket of steam.

4. The trapped steam pocket rapidly condenses, causing the bubble to collapse and creating a pressure wave due to the impact of the water.
WHY SO FEW FAILURES?
THE YETI EFFECT

• JOUKOWSKY EQUATION PREDICTS VERY HIGH CIWH VALUES—NOT REALISTIC

• MANY FACTORS LIMIT THE ACTUAL IMPACT OBSERVED
  • SIZE OF THE COLLAPSING BUBBLE
  • PRESSURE OF STEAM
  • PRESENCE OF BUBBLES/NON–CONDENSABLES IN WATER
  • PRESENCE OF ENTRAINED WATER DROPLETS IN VAPOR
  • FRICTIONAL EFFECTS OF WALLS ON WATER ACCELERATION

• EXPERIMENTS SHOW A LARGE RANGE OF PRESSURES FOR THE SAME CONDITIONS
  • ONLY A FEW REACH DANGEROUS LEVELS
AVOIDING CIWH

PIPING LAYOUT IS CRITICAL
• ONLY OCCURS IN HORIZONTAL RUNS WHERE L/D > 24
• WILL NOT OCCUR IN PIPING WITH MORE THAN 5 DEGREE ANGLE
• VERTICAL PIPING WILL NOT EXPERIENCE CIWH
• DEAD LEGS, COMMON HEADERS, LACK OF DRAINAGE ALL POSE RISKS

PHYSICAL PROPERTIES ARE CRITICAL
• OCCURS ONLY IF WATER IS >20°C BELOW STEAM TEMP
• STEAM PRESSURE DIRECTLY IMPACTS MAXIMUM HAMMER PRESSURE

Rule #1: Don’t mix steam and cold water!
STEAM ASSISTED GRAVITY DRAINAGE – SUMMARY

1. 2 PARALLEL HORIZONTAL WELLS ARE DRILLED, VERTICALLY OFF-SET.

2. STEAM GENERATED IN THE PLANT IS PUMPED DOWN THE TOP WELL.

3. BITUMEN MELTS AND A BITUMEN/WATER MIX IS RECOVERED FROM THE BOTTOM WELL.

4. OIL AND WATER ARE SEPARATED AT THE PLANT.

5. RECOVERED (PRODUCED) WATER IS CLEANED AND RE-USED. 90% OR MORE MUST BE RECYCLED.

6. BITUMEN IS COMBINED WITH A DILUENT AND SHIPPED.
WHY IS CIWH AN ISSUE FOR SAGD?
PAST HISTORY

MEG ENERGY PIPELINE FAILURE

• 24” STEAM PIPELINE SUPPLYING SAGD WELLS

• PIPELINE FAILED CATASTROPHICALLY AND RUPTURED

• REGULATOR CONCLUDED FAILURE WAS DUE TO CIWH
STEAM PRODUCTION IN SAGD

• SAGD PLANTS:
  • PRODUCE HIGH PRESSURE STEAM (>1000 PSI)
  • PRODUCE STEAM WITH HIGH CONDENSATE CONTENT
  • SHARED PIPING AND HEADERS
  • HAVE LARGE STEAM PIPELINES TO PRODUCTION WELLS

BFW Supply → OTSG’s → To Pipeline

HP Separator

LP System
ONCE-THROUGH STEAM GENERATORS (OTSG)

• AN OTSG IS NOT A BOILER!

• WATER FLOWS THROUGH THE OTSG IN TUBES. THERE IS NO DRUM.

• GENERATED STEAM IS TYPICALLY 75–85% QUALITY.

• INDIVIDUAL OTSG’S TYPICALLY PROCESS OVER 100,000 KG/HR OF WATER.

• A SINGLE ‘PHASE’ IN A SAGD PLANT WILL TYPICALLY BE 4 TO 6 OTSG’S WITH SUPPORT EQUIPMENT.

• EACH OTSG SUPPLIES STEAM FOR MULTIPLE
STEAM PRODUCTION ISSUES

• START-UP DESCRIPTION:
  • WATER FLOW BEFORE FLAME
  • FLOW IS KEPT IN THE LOW PRESSURE HEADER DURING LIGHT-OFF
  • RAPID HEATING – STEAM IN WATER
  • SWITCH FROM LP TO HP HEADER

• RISKS:
  • SHARED HEADERS
  • THE LP HEADER IS FLOODED AT EVERY START
  • RISK OF DEAD LEGS, LOW POINTS COLLECTING CONDENSATE
  • POTENTIAL FOR BFW TO BE SENT INTO HP HEADER
STEAM PRODUCTION ISSUES

• TRIPS/SHUTDOWNS:
  • GAS AND FLAME TRIPPED AS A RESPONSE TO MOST FAILURES
  • WATER FLOW IS MAINTAINED TO COOL TUBES
  • FLOW DUMPED FROM HP TO LP HEADER

• RISKS:
  • DUMPED FLOW WILL FLASH IN THE LP SYSTEM
  • LP HEADER MAY HAVE TRAPPED CONDENSATE
  • SYSTEM FAILURE/OPERATOR ERROR CAN OPEN HP FLOW INTO THE LP HEADER
STEAM TO THE WELLS

- STEAM PIPELINE

  DESCRIPTION:
  - HIGH PRESSURE (> 1000 PSI)
  - LARGE DIAMETER
  - LONG (SEVERAL KILOMETERS)
  - FOLLOW GROUND CONTOURS

- FEW STEAM TRAPS
- MINIMAL INSTRUMENTATION
- LINES RUN PARALLEL TO BITUMEN, GAS LINES
STEAM PIPELINE ISSUES

• START-UP:
  • START FROM COLD PIPE, ZERO PRESSURE
  • START-UP IS SLOW
  • CONDENSATE PRODUCED AT HIGH RATE
  • WEATHER CAN BE AN ISSUE

• RISKS:
  • CONDENSATE IS COLD
  • CONSTANTLY CHANGING TEMPERATURE, PRESSURE
  • EQUIPMENT FAILURES, DELAYS, ARE COMMON
STEAM PIPELINE ISSUES

• TRIPS:
  • PLANT WIDE TRIPS (POWER, CONTROL SYSTEMS, GAS, ETC.) STOP STEAM PRODUCTION
  • STEAM PIPELINES LOSE PRESSURE QUICKLY

• RISKS:
  • LOST PRESSURE = LOST TEMPERATURE
  • INABILITY TO READ PIPELINE LEVELS, TEMPERATURE
  • DIFFICULTY REMOVING CONDENSATE IN EMERGENCIES
  • PRESSURE TO RE-START QUICKLY
STEAM TO THE FORMATION

- SAGD WELL DESCRIPTION:
  - GROUPED INTO PADS OF MULTIPLE WELLS
  - STRICT PRESSURE CONTROLS ON FEED
  - MULTIPLE OPERATING MODES
  - SENSITIVITIES CHANGE AS WELL AGES
  - LONG HORIZONTAL RUNS
  - SENSITIVE TO OUTAGES
WELL CIRCULATION ISSUES

- CIRCULATION DESCRIPTION:
  - STEAM IS INJECTED TO BOTH WELLS
  - CHAMBER IS NOT DEVELOPED
  - OPERATED IN START-UP FOR 60–90 DAYS

- RISKS:
  - LOST STEAM CAN CAUSE RAPID COOLING
  - FORMATION GEOLOGY IS NEVER CERTAIN
SAGD CONVERSION ISSUES

• CONVERSION DESCRIPTION:
  • STEAM TO PRODUCER IS STOPPED
  • OCCURS AFTER PRESSURE TRANSMISSION PROVED
  • WELLS CAN BE STARTED ON LIFT GAS OR ESP

• RISKS:
  • UNKNOWNS IN PIPE AND FORMATION
  • POTENTIAL FOR STEAM BLOW-THROUGH TO PRODUCER
  • VERY LIMITED INSTRUMENTATION
Risk management is the process of identifying, evaluating, and mitigating the uncertainties of business outcomes.
CPF DESIGN RECOMMENDATIONS

• REDUCE SHARED HEADERS
  • ALWAYS ENTER A SHARED HEADER AT THE TOP
  • ALWAYS LEAVE A SHARED HEADER AT THE BOTTOM

• ENSURE DRAINAGE IS NOT BLOCKED BY ELEVATION CHANGES

• STEAM TRAPS ARE NOT ALWAYS ENOUGH

• MINIMIZE LONG HORIZONTAL LINES

• CIWH POORLY UNDERSTOOD – ENSURE ADEQUATE REVIEW

• RISK NOT APPARENT ON P&ID’S – MODEL REVIEWS ESSENTIAL
CPF OPERATION RECOMMENDATIONS

• TRAIN OPERATORS, MAINTENANCE, ENGINEERING AND MANAGEMENT IN CIWH
• ALARM STEAM TRAPS
• ADD INSPECTION PORTS TO PIPE INSULATION
• INTERLOCK BLOWDOWN SYSTEMS
• MONITOR TEMPERATURE AND LEVEL IN CRITICAL PIPING
• DON’T DRAIN UNDER PRESSURE
• WRITE, REVIEW, RETAIN DETAILED PROCEDURES
PIPELINE AND WELL RECOMMENDATIONS

• ROBUST PIPELINE CONDENSATE STATIONS
• INCREASE MONITORING ON PIPELINE P, T
• ALARM/INTERLOCK ON LEVEL AND TEMPERATURE
• DESIGN WELL-PADS FOR STABILITY
• IMPROVE WELL MONITORING
• WRITE, REVIEW, RETAIN DETAILED PROCEDURES
THANK YOU/QUESTIONS?

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