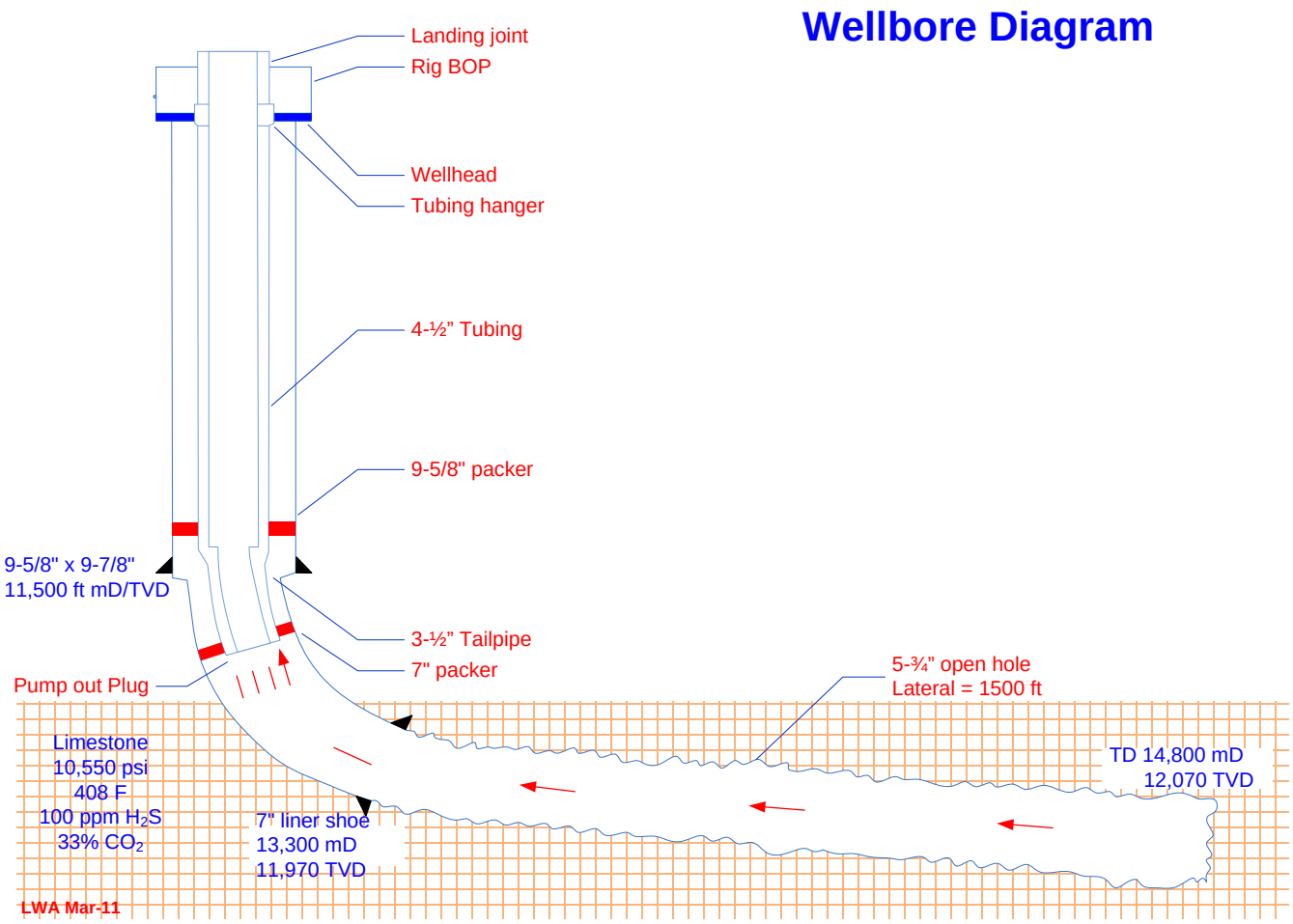
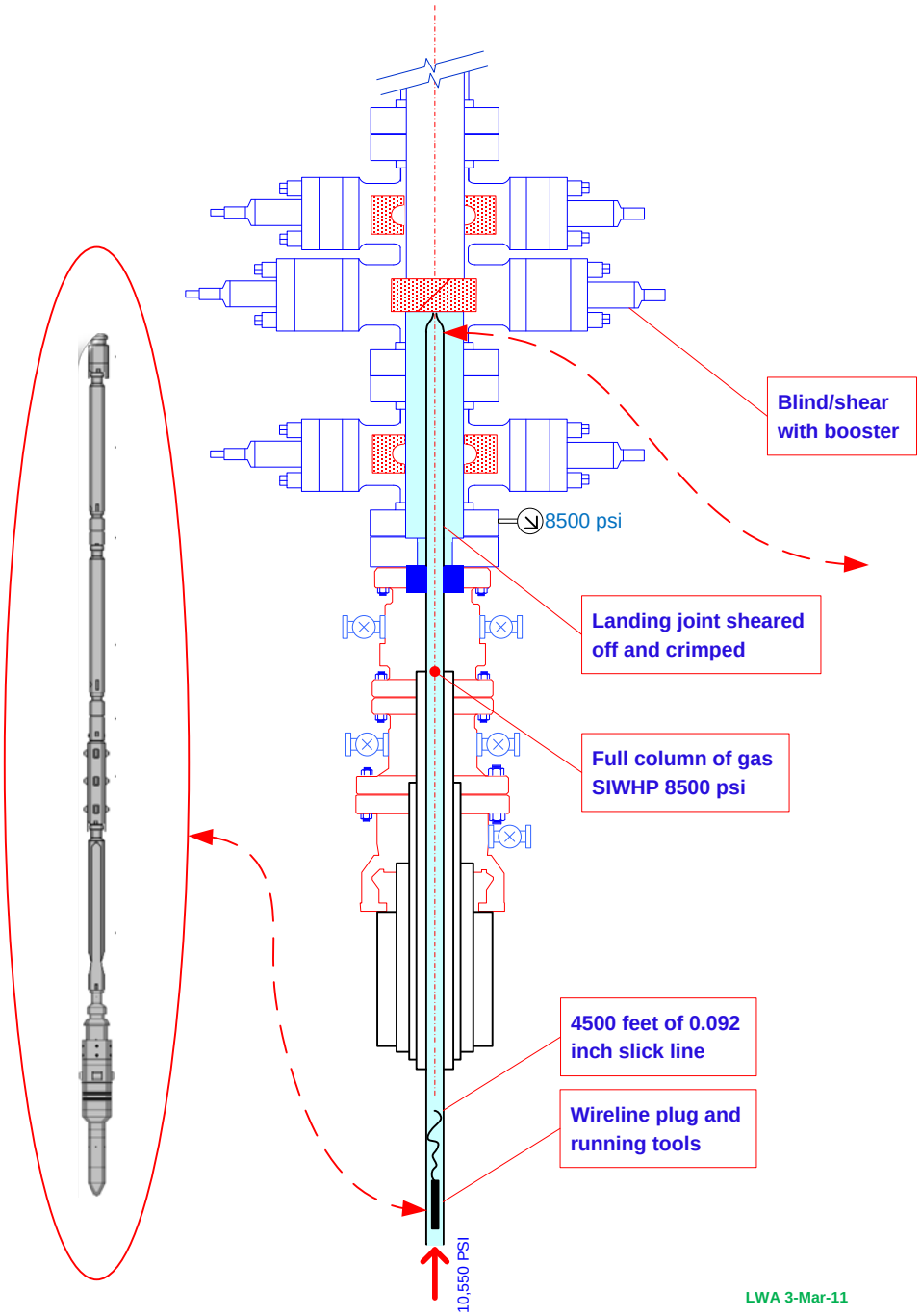
FREEZE CASE HISTORY

The Problem

The well was drilled with a statically underbalanced mud weight in MPD mode in HTHP conditions of 10,550 psi, 408F, 32% CO2, 200 ppm H2S to a depth of 14,800 ft mD (11980 ft TVD). A 7 inch packer was snubbed in to isolate the HP reservoir while a chrome completion was run in the well with an upper 9-7/8" packer assembly. This operation was completed successfully and the tubing was hung off in the wellhead and the well bore was as per the figure below:



During the process of setting the upper packer the pump out plug in the lower packer exited its seat and upon pulling a wireline plug the well free flowed up the tubing to the rig floor. The wireline crew was unable to stop the flow, therefore the rig BOP was employed to shear the landing joint. The landing joint was sheared successfully, the flow stopped and the pressure on the rig BOP stabilized at 8500 psi. The wireline, running tools and the plug were left in the well. The well could not killed by bullheading because the plug was floating in the well and would set on its seat thus acting like a check where flow up was allowed but flow downwards was not possible. Lubrication of fluid was not a feasible option either (several attempts were made with no success) due do solubility of gas and oil based kill fluid. Several attempts were made to kill the well and all were successful. The situation was as per the diagram below:



Thus the obstructions (fish) in the well were:

a) Wireline plug and running tools

b) Slick line (about 4500 feet) in chunks and bird nested

c) Sheared and crimped landing joint

d) Some solids from the open hole and OBM

The Dilemma

The problem after shearing the landing joint was that the well could not be re-entered, killed by pumping from the top (bullheading failed and volumetric failed) and wireline could not pass the crimped top of the sheared top of the landing joint. There was 8500 psi on the well and the BOP was past its testing period of 14 days. Well control "experts" from the name brand companies were consulted and they all recommended that the rig be skidded off and a snubbing unit be rigged up for fishing out the landing joint and wireline fish in the well. The owner of the well did NOT want to kill the well as the well was drilled MPD and killing the well would un-do the advantage of the MPD operation and severely damage the formation thus causing a heavy economic impact on gas deliverables. Fishing out wireline with snubbing techniques is very awkward under high pressure and could easily develop into a lengthy and costly operation that would result in damaging the well (scarring the inner bore of the special corrosion resistant materials. In an ordinary situation, Heavy Duty Wire Line would be employed to fish out the slick line and slick line tools and the plug. With the sheared off landing joint this was impossible until the landing joint was removed. The situation was summarized as follows:

- Well control experts said it is a snubbing job cannot be fixed otherwise
- Intuition says it's a HDWL job but the sheared landing joint prevents that work
- Pressure on the well prevented removal of the landing joint unless snubbing was employed (snubbing alone was estimated at $5m)

The Solution

ABEL Engineering with their knowledge of well control operations and in particular freezing operations developed a plan to freeze the wellhead and the tubing near the surface to isolate the wellhead pressure below the hanger. This would allow the BOP to be opened and the sheared off landing joint removed clearing the well from the hanger up. The plan was then to install a BPV in the hanger. Then to remove the BOP and install a tree. The freeze idea was proposed to:

- Boots n Coots
- Cudd Pressure Control
- Halliburton Energy Services

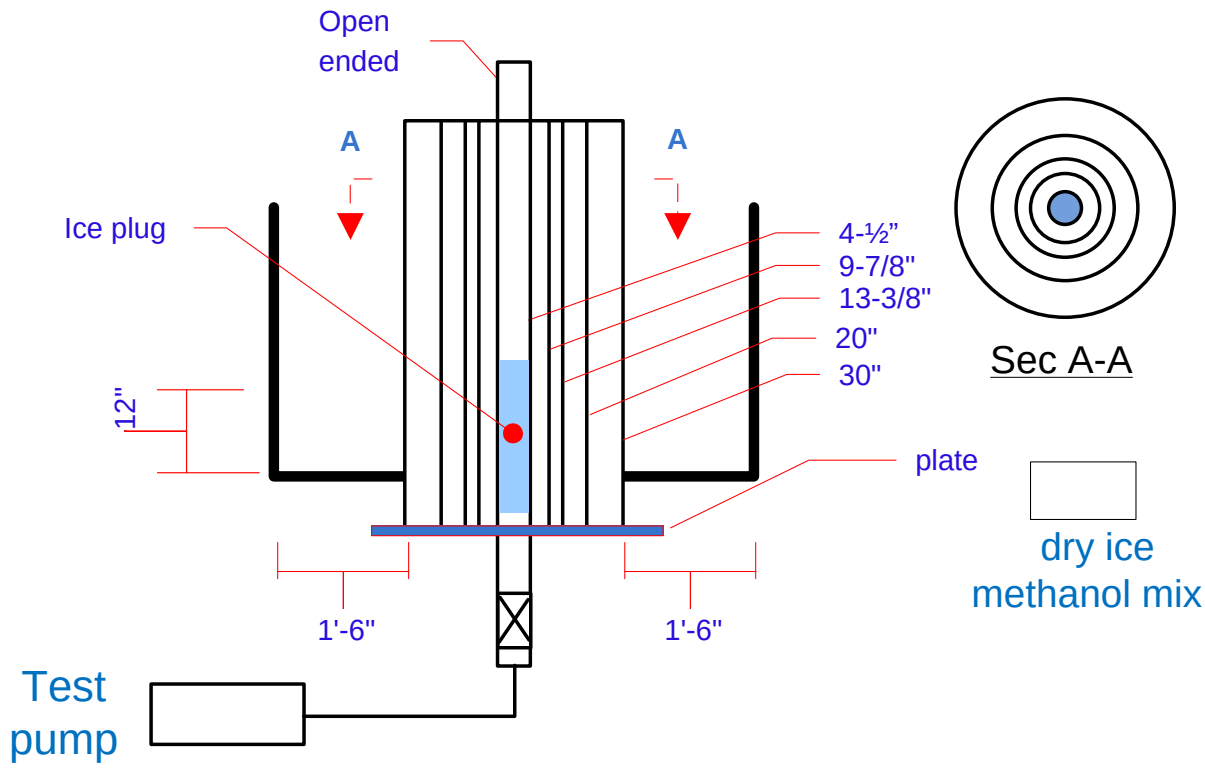
The well control companies said that freezing would not work as the pressure were too high for any freeze to work and one would never effect a freeze to an inner string thru multiple string and the wellhead. Halliburton endorsed the freeze but could not mobilize an expert to site quickly due to visa issues and personnel availability. ABEL Engineering studied the problem and agreed with HES that the freeze could be done safely and effectively.

Proving The Technique

Several issues existed as the ice plug once in place potentially would the only barrier that would prevent a blowout where a capping job or relief well would be required. The two main issues were:

- could an inner string be frozen (thru multiple strings) and
- would the ice plug when in place hold 8500 psi.

A mock up was constructed on site to prove and test the technique as per the diagram below:



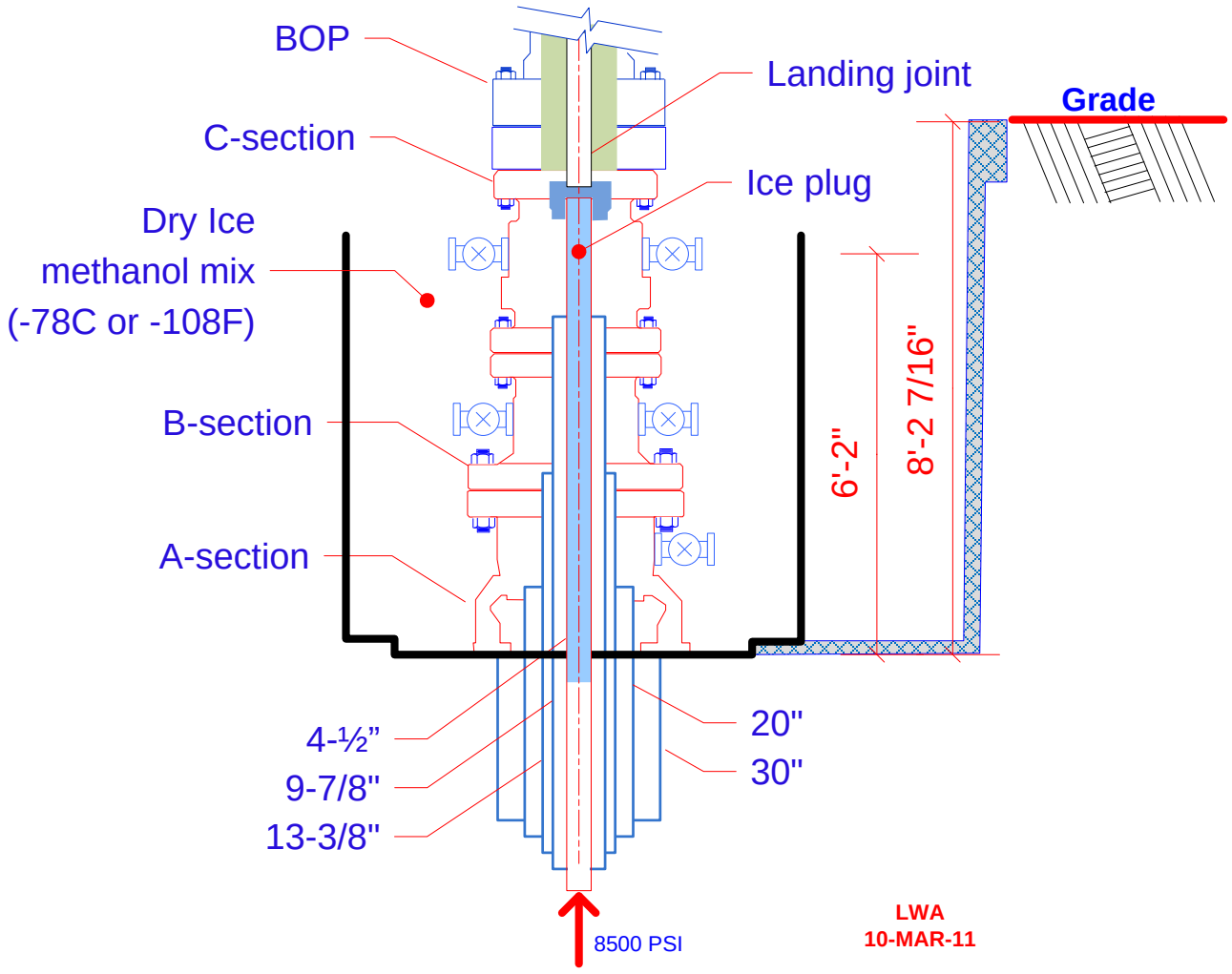
The inner strings were filled with water and the tubing filled with gel water mix (the freeze fluid to be forced into the tubing in the well). Dry ice and methanol mix was placed only 12 inch high in the tub so that the freeze plug would have limited height. After freeze was affected (tested by tagging from the top with a rod) the plug was pressure tested to 8500 psi for one hour. Then the pressure was increased until failure. The failure was observed at 10,100 psi. The Ice Plug was measured to be 14 inches in length. All tubulars used in the mock up test were identical (drops from the well construction) to the pressurized well. The results of the mock up proved that an inner string thru 4 (four) strings could be frozen, the ice plug would form in less than 8 hours and a 14 inch plug inside 4-1/2" tubing would hold 10,000 psi. It was surmised that longer plugs would hold higher pressure.

Temperature Effects

The metallurgy by the suppliers was confirmed that -78C would not harm the metal. However a caution was given that the impact (brittle) strength was affected and that impact loads (hammering, dropped objects, etc.) could cause a crack in the metal. Also that after the temperature was allowed to return to ambient or to well flowing conditions (elevated temperatures) that no effect on strength would occur by taking the temperature down to dry ice and methanol mix temperatures.

The Freeze Job

The freeze was accomplished by building a wooden frame around the wellhead. Then water was forced into the annuli of the outer strings (30x20; 13-3/8”x9-7/8”; 9-7/8”x 4-1/2”). The freeze material was a heavy gel / water pill and about 12 bbls were forced into the tubing via the kill line on the BOP. The pressure was taken to 10,000 psi to accomplish this. The gel pill caused the pill to stay in place while the wellhead head was cooled. Dry Ice from several locations around Indonesia was shipped via air freight to the nearest airport and then trucked to the site in Styrofoam containers. A container of about 8 bbls was used to mix the dry ice with methanol. This slush mixture was placed around the wellhead so that the top of the dry ice was mid-way on the C-section (tubing head). As the ice sublimated (evaporated) it was replaced every hour with a slush of dry ice and methanol. After some time the methanol evaporated leaving only packed dry ice. The temperature of dry ice at sea level is -108F. After 24 hours the pressure on the well was reduced in increments to zero.



The BOP Removal and Tree Installation

The freeze was flow tested for 24 hours and observed to be zero. It then thought to be safe to open the BOP and see the condition of the landing joint. It was found to be crimped and flattened by the shearing process. A “reverse” screw driver fishing tool was then used to retrieve the landing joint by backing it out and grabbing it. Then this was done, a section of wireline was seen across the hanger profile which prevented the BPV from being installed. The next step was to lift off the BOP, clean out the hanger profile and cut the 0.092 wire and to install the BPV in the tubing hanger. This was accomplished in about 1 hour. A 10k tree was then installed. While this procedure does NOT meet the dual barrier “rule” per se it does prove that:

1. an Ice Plug when properly implemented can hold high pressures

2. there is sufficient heat transfer across multiple strings (> 15 inches) that allow water to be frozen

3. dry ice sublimation temperature (-108F) does NOT change the metal properties or cause brittle problems

4. dry ice and methanol can be handled safely and efficiently

5. the overall method is simple to implement and manage (avoids costly N2 apparatus now employed by other “experts”

Conclusion

Freezing a tube (in this case 4.5 inch chrome) to form an ice plug will effectively create an isolation plug that will hold in excess of 10,000 psi for as long as the plug remains frozen. It can be done quickly and efficiently using ordinary consumables found in drilling operations, namely water, gel, pumps and dry ice (from the local market).

Photo Gallery BOP Removal and Tree Installation

Below are photos taken during the freeze operation described above.

BOP stack up with 8500 psi under the blind ram

Methanol Dry Ice Mix Bucket

Reverse “screw driver” used to back off the landing joint

Sheared off lower section of landing joint after recovery

Top of sheared off landing joint (crimped during shearing – bent while fishing out)

x 

Recording wellhead temperature with handheld device

"Moment of Truth" BOP is lifted off the wellhead with only ice holding pressure

Top of C-Section (tubing hanger) upon lifting off the BOP
(Note the 0.092 wire and ice that formed 2 feet above top of dry ice application)

Installation of the BPV in tubing hanger (second barrier installed)

Installation of the tree (well fully secured!)