SAMPLING AND QUALITY ASSURANCE

1. Laboratory samples and testing conditions must be representative of field materials and conditions. (Vendors sometimes provide samples to labs that are different from field products.)
2. Water used in lab tests must be representative of field water. (Field & lab people MUST communicate any important changes, like water source changes.)
3. Lab tests in the field MUST verify the behavior of delivered products (e.g., polymer ability to dissolve, polymer solution viscosity, gel times).
4. Pumps, mixers, and filters must not shear degrade the polymer.
5. Field samples for testing should be drawn near the wellhead.

POLYMER HANDLING

Solid grade polymer (>90% active):

- Minimizes shipping costs.
- Requires specialized mixing equipment.
- Residue or incomplete hydration creates fisheyes.

Solution concentrate (~20% active):

- Easily pumped and diluted
- Less complex mixing equipment.
- Can be prepared “on the fly”, minimizing waste.
- Has significantly higher shipping costs.

Liquid, slurry, or emulsion polymers (30-50% active):

- Easily pumped and diluted (if lines are clean & dry).
- Less complex mixing equipment; injection on the fly.
- Intermediate shipping costs.
- Special care required for clean dry lines, tanks, etc.

FILTRATION

Views vary on what and where filters should be used.

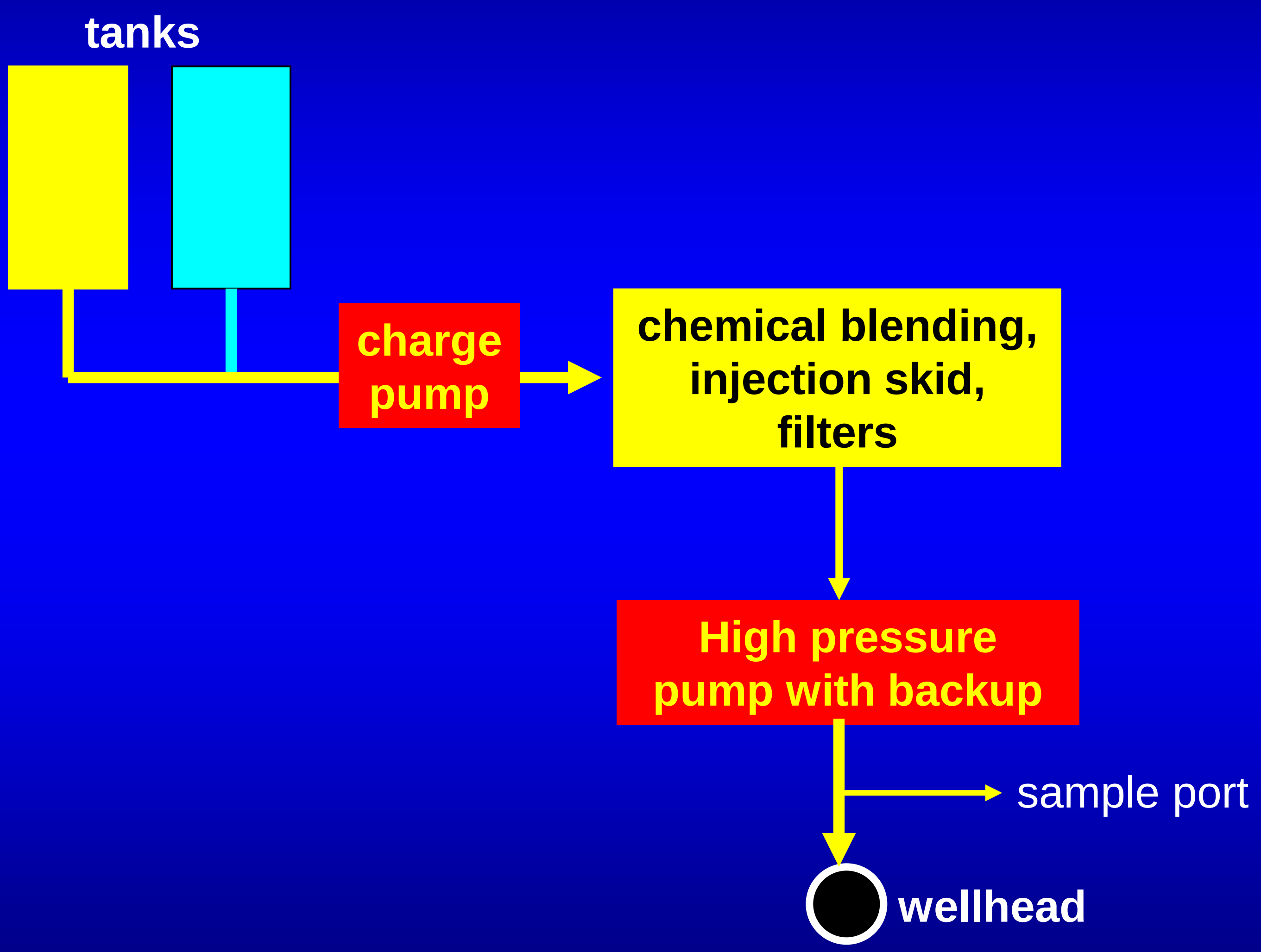
Advisable to have two filters (10 µm) in parallel downstream of the mixing equipment.

- Avoids well plugging.
- Gives a quality check on polymer preparation.

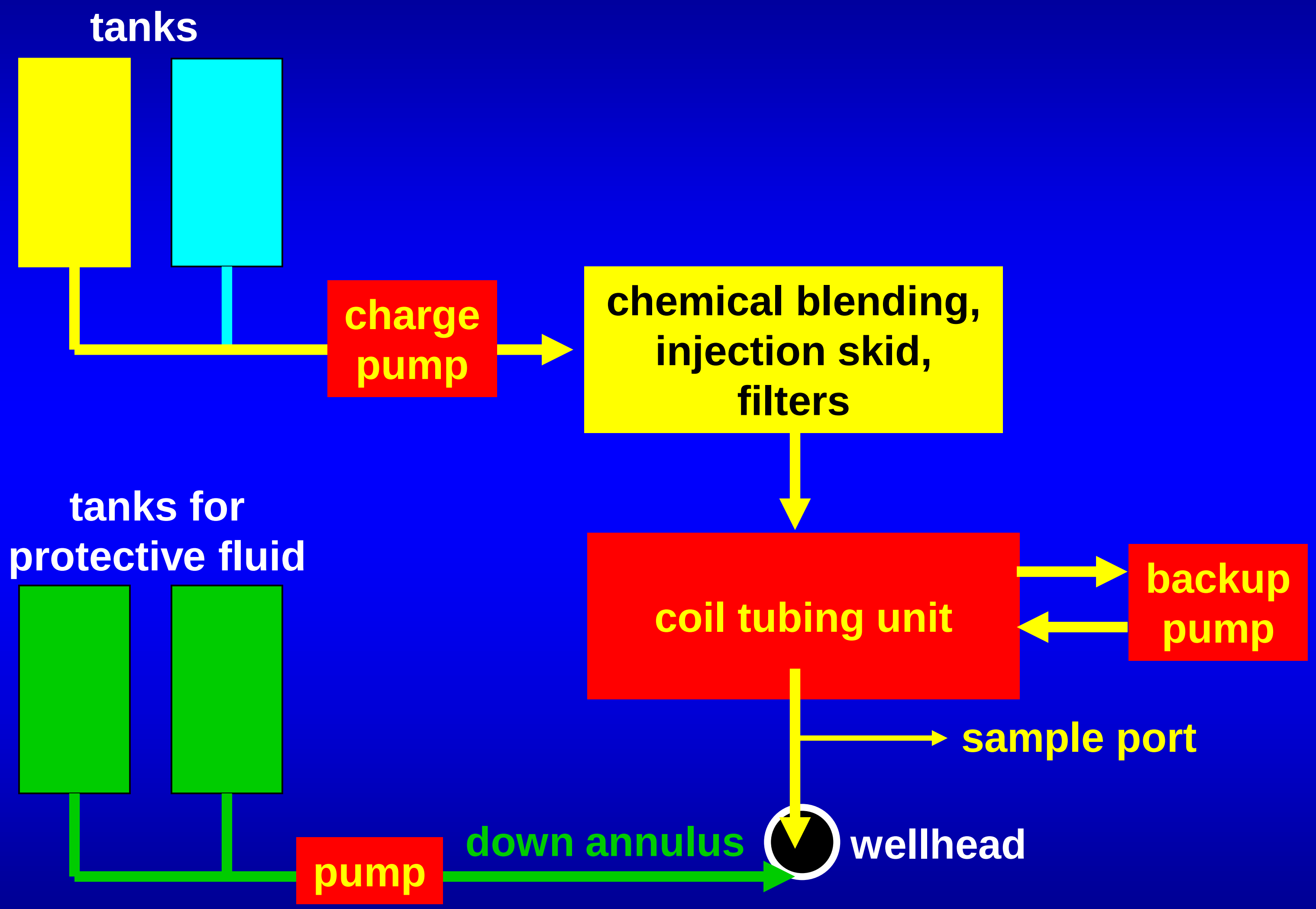
RIG UP ISSUES

1. Many equipment configurations are possible.
2. Other things being equal, simpler is better.
3. All transport trucks, tanks, hoses, pumps, lines and mixing equipment MUST be clean and inspected by someone who has a major stake in project success.
4. “Clean” means carefully flushed with water compatible with gelant.
    - Residual water must be clear with neutral pH.
    - No oily or solid residues.
    - With slurry polymer, lines, tanks, etc. must be DRY.
5. Temperature extremes should be avoided, especially for connecting hoses.

SIMPLE RIG UP EXAMPLE



COMPLEX RIG UP EXAMPLE



RIG UP ISSUES—TANKS, PUMPS & HOSES

1. Many tank options exist (frac tanks, transport trucks, etc). Tanks should be sized so refilling and switching occurs at reasonable times (hours not minutes).
2. Low-pressure hoses, tanks, charge pumps, blenders, and filters used before the final high pressure pump.
3. Pumps, mixers, and filters must be selected to minimize mechanical degradation of the polymer.
4. Locate filtration equipment at blender discharge.
5. Although “on the fly” mixing is conceptually attractive, polymer mixing is often inadequate.
6. High pressure injection pump is the final equipment before the wellhead.
7. Sample port must be close to the wellhead.

TREATMENT EXECUTION ISSUES

1. Gelation time usually determines the pump time (except for some large treatments in fractures).
   - Downtime during pumping must be avoided.
   - Good polymer/gel quality control is needed.
   - Equipment redundancy can reduce downtime.
2. Surface equipment may limit the surface pressure. It’s best to have a pump with a high rate limit.
3. Parting pressure often limits downhole pressure.
4. Pressure drop from surface to formation is usually negligible unless coiled tubing is used.
5. Hall plots help monitor pressure trends. (They do NOT indicate where the gel is placed.)

CHEMICAL INCOMPATIBILITIES

- Cationic corrosion inhibitors precipitate with anionic polymers (e.g., HPAM).
- Scale inhibitors can destroy gels made with metal crosslinkers [e.g., Cr(III)].

- Don't apply these chemicals too soon before or after a gel treatment.
- Check lines, equipment and make-up water for these contaminants.
- Lab tests may help to establish compatibility.

- Rust, crude components, emulsion breakers, defoamers, water clarifiers, floatation aids, oxygen scavengers, H_2S, and chlorine may affect gel chemistry.

POST-TREATMENT WELL OPERATIONS

- Shut-in times depend on the gel and the nature of the problem treated.
- After shut-in, bring the well back into full service gently (over the course of days or weeks rather then hours).
- Post-treatment procedures should consider whether the gel treatment will be compromised (corrosion inhibitors, injecting above parting pressure, acid jobs, etc.).

REVIEW OF THE MOST IMPORTANT CONCEPTS

- The cause of the water production problem must be identified.
- Different design, sizing, and placement procedures must be used for different types of problems.
- For radial flow, hydrocarbon-productive zones must be protected during placement of chemical blocking agents.

GEL TREATMENTS ARE NOT POLYMER FLOODS

Crosslinked polymers, gels, gel particles, and "colloidal dispersion gels":

- **Are not simply viscous polymer solutions.**
- **Do not flow through porous rock like polymer solutions.**
- **Do not enter and plug high-k strata first and progressively less-permeable strata later.**
- **Should not be modeled as polymer floods.**

A STRATEGY FOR ATTACKING EXCESS WATER PRODUCTION

1. Consider and eliminate the easiest problems first.
2. Start by using information that you already have.

Excess Water Production Problems and Treatment Categories
(Categories are listed in increasing order of treatment difficulty)

Category A: "Conventional" Treatments Normally Are an Effective Choice

1. Casing leaks without flow restrictions.
2. Flow behind pipe without flow restrictions.
3. Unfractured wells (injectors or producers) with effective crossflow barriers.

Category B: Treatments with Gelants Normally Are an Effective Choice

4. Casing leaks with flow restrictions.
5. Flow behind pipe with flow restrictions.
6. "Two-dimensional coning" through a hydraulic fracture from an aquifer.
7. Natural fracture system leading to an aquifer.

Category C: Treatments with Preformed Gels Are an Effective Choice

8. Faults or fractures crossing a deviated or horizontal well.
9. Single fracture causing channeling between wells.
10. Natural fracture system allowing channeling between wells.

Category D: Difficult Problems Where Gel Treatments Should Not Be Used

11. Three-dimensional coning.
12. Cusping.
13. Channeling through strata (no fractures), with crossflow.

KEY QUESTIONS IN OUR APPROACH

1. Does a problem really exist?
2. Does the problem occur right at the wellbore (like casing leaks or flow behind pipe) or does it occur out beyond the wellbore?
3. If the problem occurs out beyond the wellbore, are fractures or fracture-like features the main cause of the problem?
4. If the problem occurs out beyond the wellbore and fractures are not the cause of the problem, can crossflow occur between the dominant water zones and the dominant hydrocarbon zones?

Respect basic physical and engineering principles.
Stay away from black magic.

MAIN POINTS I THINK YOU NEED TO KNOW

1. What polymers, gelants, and gels can/cannot do.

2. Why determining whether flow is radial (into matrix) or linear (through fractures) is critical in EVERY application.

3. A strategy for attacking problems.

PROPERTIES OF AVAILABLE GELANTS/GELS

1. Early in the gelation process, gelants penetrate readily into porous rock.

2. After gelation, gel propagation through porous rock is extremely slow or negligible.

3. The transition between these two conditions is usually of short duration.

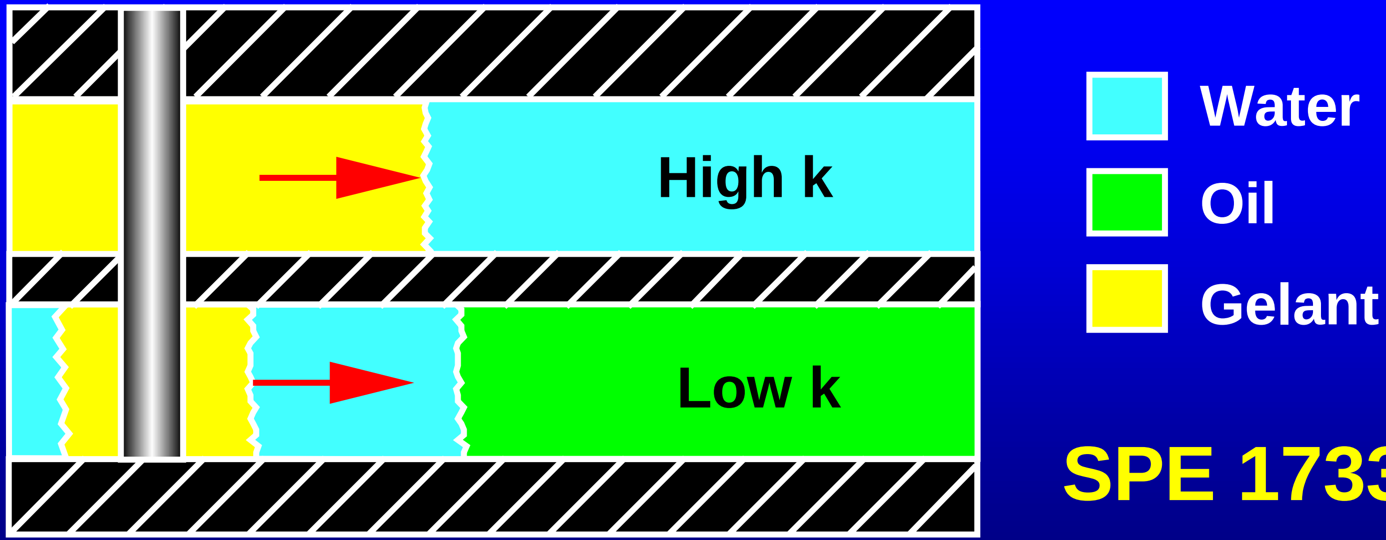
SPERE (Nov. 1993) 299-304; *IN SITU* 16(1) (1992) 1-16; and *SPEPF* (Nov. 1995) 241-248.

BASIC CALCULATIONS

Gelants can penetrate into all open zones.

An acceptable gelant placement is much easier to achieve in linear flow (fractured wells) than in radial flow.

In radial flow (unfractured wells), oil-productive zones must be protected during gelant placement.



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