Chapter 11: Commissioning Studies

11.1 Introduction

It is not easy to specify RCAL and SCAL programmes on a general basis. Each reservoir (or well) has to be considered on its own merits. The numbers of each particular test required will depend on the permeability/porosity distribution. The range of tests required will depend on previous experience with the particular reservoir rock/fluid combination under study. Where previous experience is available and there is good agreement between routine core analysis, log and well performance data, the numbers of tests and possibly scope can be reduced. Where anomalies exist it will be advantageous to increase coverage of some parameters and possibly introduce special test sequences to assess the more unusual core and fluid interactions connected with formation damage.

The more common reservoir situations encountered are summarised below. In each case it is the SCAL that has been concentrated upon. Routine core analysis commissioning is usually done by internal protocol. For example, plugging every foot wherever the strength of the core fabric allows it, basic chemical cleaning, and then He porosity and gas permeability on the core plugs. Sometimes Hg porisimetry, CT scanning and petrographic analyses are also carried out on a small number of plugs.

When commissioning a SCAL study the **FIRST** step is to review **ALL** the RCAL data that has already been obtained. The RCAL information effectively provides a pre-study that will help identify possible problems in carrying out the SCAL work. These problems may include (i) swelling clays, (ii) friable and unconsolidated core, (iii) drilling fluid contamination, (iv) mobile fines, etc.

Also, it is important to seek the technical advice and expertise of:

- Anyone with experience of the rock properties for the field in question.
- The technical staff and managers carrying out the work.
- Any other individual or source that may provide data that could help save expensive mistakes.

Remember time is money, but if corners are cut such that the real requirements are not well defined, or data that you already have is not used, or possible problems with the rocks are not recognised, then more money will be wasted. SCAL data is very expensive to collect. Hence, ask yourself the following points during SCAL commissioning:

1. What data do you have already from RCAL?
2. What other knowledge is there that you can draw upon?
3. What is the type of field, drive and hydrocarbon?
4. What do you want to do with the SCAL data?
5. Will your projected SCAL campaign provide sufficient data for the purpose it was designed - Is it fit for purpose?
6. Is there any information that would be missing? If it is required, commission it!
7. Is there a specified test that will not tell you any further information concerning the field? If there is drop it!

8. Have you commissioned sufficient cores of each type of test to provide a reliable and representative coverage of the well section of interest? If you do not know how to judge this, get advice!
9. Does the data you have flag any possible problems with the particular rock to be analysed? If there are problems you must talk to the people carrying out the tests. They should be warned of problems, and in most cases will be able to advise you on the best technical approach to either overcome, avoid or minimise the problem.
10. Does the service company know your needs sufficiently well to provide good and informed service? Good communications leads to better data!
11. Have you asked the service company managers and technical staff for their expert advice?
12. Do you know the timescale for the scheduled work, and is it fixed? If not fix it – SCAL tests are of known duration and can be scheduled well.
13. Have you specified the errors that are acceptable on the measurements? To do this you will need to communicate with the service company. Ensure that measurement errors, which always occur, are sufficiently small or manageable that the data is fit for purpose.
14. Have you specified the data to be provided in a format that will the of best use to you, i.e., on CD-ROM in Excel format as well as a written report?

A little time spent planning can save an enormous amount of money.

11.2 Dry Gas Reservoirs

These represent the simplest case but the relative importance of the suggested tests (Figure 11.1) will depend upon the nature of the reservoir. Particular care should be taken with highly fractured reservoirs where gas/brine contacts move rapidly. Measurement of trapped gas saturation is particularly important here. With sandstone reservoirs brine permeability in the water zone may be significantly lower than indicated by routine measurements. This can be readily assessed from a relatively small number of tests on *preserved* water zone cores.

Figure 11.1 Basic SCAL Programme for a Dry Gas Reservoir 100' Thick with a Single Facies Type

	Test Sequence	Number of Tests Proposed	Typical Charge per Test (Man-hours)
1	Drill, trim and clean by flushing as many plugs as are obtainable from preserved core (up to 60)	As required	-
2	Capillary pressure (air-brine) Resistivity index Saturation exponent Formation factor Cementation factor	10-20	15
3	Formation factor at overburden pressure Pore volume compressibility at overburden pressure Brine permeability at overburden pressure	10-20	12
4	Ambient condition relative permeability gas floods Drainage and imbibition cycles	10	30
5	Water zone permeabilities Brine permeabilities of preserved core - plug samples	5	6
6	Clean by routine methods Routine porosity (He method) KL gas permeability	As required	-
7	Plug description, thin section, and SEM studies to link SCAL properties with sedimentological characteristics	As required	-
	Typical cost	**700-1000 man-hours (approximately £800,000)**	

11.3 Oil Reservoir without Gas Cap

The situation with oil reservoirs becomes more complex than a dry gas reservoir as:

(i) Transition zones are usually from a more significant portion of the reservoir.
(ii) Flow characteristics and relative permeabilities are strongly influenced by wettability.

The static tests, i.e. capillary pressure, resistivity index, formation factors etc., are basically straightforward, (Figure 11.2). However, dynamic tests, i.e. relative permeability, are more complicated, and choice of type and test mode depends upon wettability. Wettability measurements should be considered as an essential preliminary to choice of relative permeability test. If waterflooding is envisaged then wettability is extremely important, as will be water zone brine permeabilities on preserved core.

Figure 11.2 Basic SCAL Programme for an Oil Reservoir 100' Thick with a Single Facies Type

	Test Sequence	Number of Tests Proposed	Typical Charge per Test (Man-hours)
1	Drill, trim and clean by flushing as many plugs as are obtainable from preserved core (up to 60)	As required	-
2	Capillary pressure (air-brine) Resistivity index Saturation exponent Formation factor Cementation factor	10-20	15
3	Formation factor at overburden pressure Pore volume compressibility at overburden pressure Brine permeability at overburden pressure	10-20	12
4	Wettability tests on preserved and cleaned core	6	15
5	Ambient condition relative permeability tests (mode chosen depending on wettability measurements)	10-15	30
6	Reservoir condition waterfloods. Possibly in preference to (5 above) depending on the characteristics of the core	Up to 6	120
7	Water zone permeabilities Pore throat size distribution measurements by mercury injection	5	10
8	Clean by routine methods Routine porosity (He method) KL gas permeability	As required	-
9	Plug description, thin section, and SEM studies to link SCAL properties with sedimentological characteristics	As required	-
	Typical cost	**700-1700 man-hours (approximately £1,400,000)**	

11.4 Oil Reservoir with Gas Cap

The static tests are basically the same as for 11.2 above. Choice of dynamic relative permeability tests will depend upon the expected movement of oil/water and gas/oil contacts. If expansion of the gas cap into the oil zone is envisaged, gas-oil relative permeability at connate water tests are desirable. Similarly if the reservoir is being waterflooded for pressure maintenance or to reduce gas cap size; the imbibition gas/oil test will provide valuable data on oil permeability at trapped gas saturation and the trapped gas saturation itself.

11.5 Gas-Condensate

The flow regimes and saturation changes which occur in condensate reservoirs are among the most difficult to model in the laboratory, and are extremely rare.

11.6 Formation Damage

The term formation damage generally describes permeability reduction brought about by:

(i) Movement of fines.
(ii) Introduction of particulate matter.
(iii) Introduction of incompatible fluids.
(iv) Introduction of fluids upsetting desired relative permeability behaviour.

It is especially difficult to specify a general scheme of formation damage tests. The particular reservoir fluids, minerals, saturation change directions, and introduced fluid compositions should be considered when defining a programme. Two situations will therefore be briefly covered which illustrate the means of damage detection and the applicability of single and two phase tests. The cases considered here are poor and declining injectivity in a water injection well, and formation damage caused by drilling muds.

11.6.1 Poor and Declining Injectivity

The possibilities here are:

(i) Particulate matter in injection water.
(ii) Mobile fines within reservoir rock.
(iii) Incompatible waters causing clay swelling.

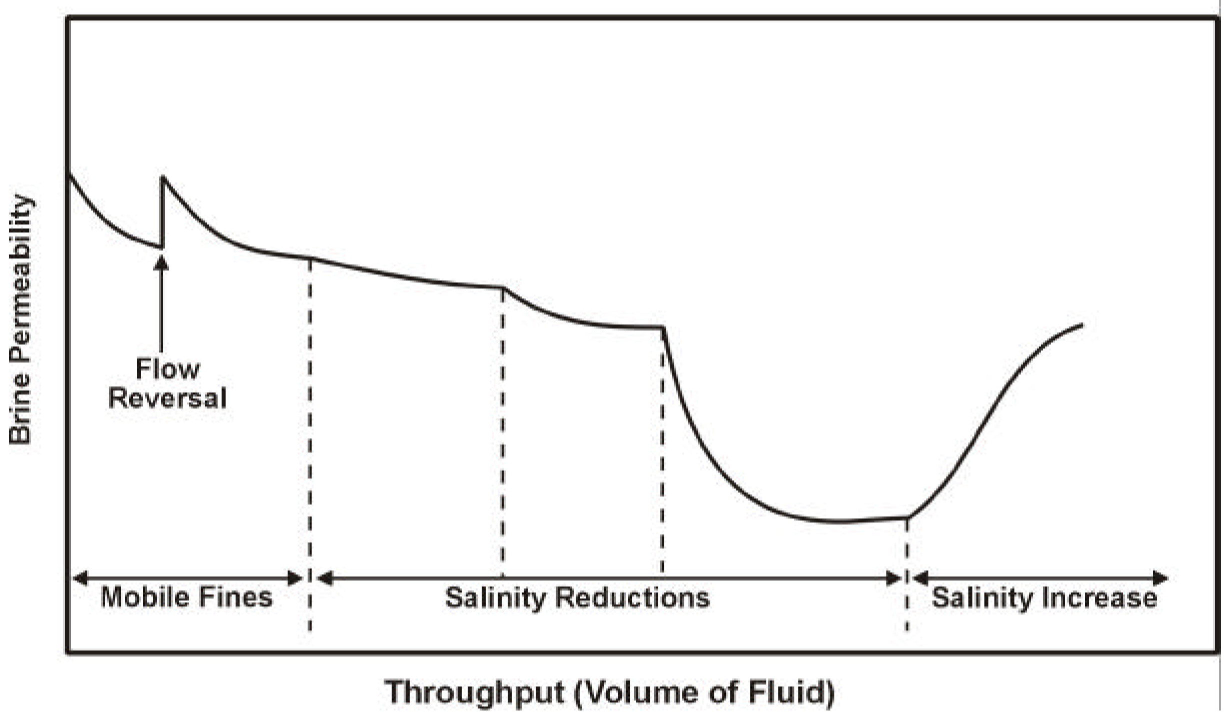
These processes can be tested for by the following methods:

(i) The problem of particulate matter in injection water should be taken care of by proper filtration but could be tested for with on site core tests. The tests however tend to be pessimistic and indicate greater permeability decline rates than are encountered downhole.

(ii) The presence of mobile fines can be detected fairly readily in the laboratory. Permeability to liquids (brines) are observed and plotted against throughput. Changes occur with throughput and flow direction when fines move to block pore throats, Figure 11.3.

(iii) The sensitivity of a formation to brine composition can be assessed by core throughput tests with changing brine compositions, Figure 11.3. Simple clay swelling effects are observed as reversible permeability changes. However, it is possible that some particles become dislodged during the tests and then behave as mobile fines.

Figure 11.3 Permeability Damage Due to Mobile Fines and Salinity Changes



10.6.2 Drilling Mud Formation Damage

A recent study indicated that single phase (liquid) permeability tests cannot necessarily be relied upon to predict formation damage for a two phase situation. Single phase tests indicated that oil based mud filtrate permeability was greater than for water based mud filtrate, implying permeability damage by the water based mud. However, when the mud filtrates were displaced with gas, the effective gas permeabilities were the same in both instances. This case has been simplified, as other factors, such as relative permeability, fluid saturations and volume throughput required to achieve recovery of gas permeability; also need to be considered when interpreting the permeability data.