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Developing Guidelines for Avoiding Moisture Problems in Energy Retrofits

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ABSTRACT

The "moisture stress raising" effects of several energy-conserving retrofit measures are noted, as well as certain relief effects which are also intrinsic. Ongoing field testing is already showing that our "cold country" houses are remarkably resilient, tolerating rather extensive retrofit. Nevertheless, increasingly extensive (and generally worthwhile) retrofits are leading to moisture-induced deterioration. The nature and probability of significant moisture problems appear to be predictable at the point of choosing energy retrofit measures, and simple, economic safeguards, relief measures and "household operations" guidelines can be tailored to suit. Such guidelines are helpful as well in "trouble shooting" houses with existing moisture problems. Energy, Mines and Resources Canada has commissioned a case study approach to develop these guidelines. Progress in developing the Moisture Assessment-Prescriptive Procedure (MAPP) is described.

INTRODUCTION AND SCOPE

The great majority of houses across inland Canada apparently remain free of substantial moisture problems, whether or not built or retrofitted with energy conserving measures. Under the more adverse climatic conditions of our coastal regions, however, many modern houses and energy-retrofitted older houses suffer condensation accumulations serious enough to cause disfigurement and premature deterioration. As noted in our earlier paper in this BTECC Symposium, flueless heating is a characteristic of much of the troubled stock; that and other extensive energy-related retrofit is capable of tipping some of our existing stock - even in inland climates - into significant trouble.

Nevertheless all of the substantial moisture problems appear readily and economically avoidable. It would be a wasteful mistake to limit the energy-conserving retrofit of most of the housing stock simply to forestall possible moisture damage to some of that stock, or to recommend broad use of safeguards that could entail far more cost (or forego more worth of energy savings) than the cost of the damage they are intended to avoid.

On the other hand, it would be a mistake to encourage unlimited energy retrofit everywhere, simply on the evidence that most houses in most regions can avoid excessive moisture accumulations when subjected to today's normal range of energy retrofit combinations. Or to assume that the more trouble-free regions will always remain so, in the face of new or increasingly intensive retrofit measures and operating conditions.

Improving the performance of the end product can be achieved by implementing just the needed type and amount of avoidance or corrective measures in concert with the energy upgrade activities. Energy, Mines and Resources Canada has commissioned Scanada to develop a practicable field guidance technique for identifying and prescribing the necessary measures. The guidelines, the Moisture Assessment-Prescriptive Procedure (MAPP), must not involve time-consuming testing with elaborate equipment and highly trained technologists, nor a diagnostic procedure that would cost more than the odd occurrence of moisture damage. Nor can it be too simplistic, yielding too little definition, too much over-prediction or too much under-prediction of problem potential.

This study makes use of the combined practical and theoretical knowledge of project team members with experience in housing and energy retrofit across Canada, as well as extensive field testing and field validation of hypotheses to ensure the development of an end product that is practicable, economic and sufficiently accurate. Beginning late last winter, the field teams have been case-studying 17 houses divided primarily between St. John's, Newfoundland and Winnipeg, Manitoba; this winter's work is well underway on those cases plus 10 in Vancouver, 9 more in St. John's, 1 in Ottawa and Toronto, and follow-up checking of 10 complaint cases addressed in previous work in Toronto. The field studies have been proceeding in the hands of Provincial Consultants Ltd., St. John's; CanAm Air Leakage Control, Toronto; SAR Ltd., Vancouver; and Scanada teams in central and Prairie areas.

This paper is a progress report, a first glimpse at a Moisture Assessment-Prescriptive Procedure which is now undergoing refinement and field-proofing.

MOISTURE STRESSING AND RELIEF ASPECTS OF ENERGY RETROFIT MEASURES

Upgrading an older house to conserve energy tends to raise the winter season "moisture stressing" of the house, primarily by reducing the air change rate and thereby raising relative humidity (RH), and secondarily by pressurizing or at least reducing the usual degree of depressurization. Most energy retrofit measures by themselves entail the primary effect, some entail the secondary as well; some reduce some types of moisture stressing while increasing others, and a few energy conserving measures are, on balance, relief measures or preventive measures that help to reduce or avoid moisture stressing.

For example, insulating a house airtightens the house a little, reducing the air change rate, and reduces it still more by decreasing the operating time of furnace and flue; this raises RH and its moisture-stressing effect. At the same time the insulation raises the surface temperatures and reduces the incidence of indoor surface condensation and mould (except at windows, framing and junctions that the insulation does not upgrade):

ENERGY-CONSERVING RETROFIT MEASURE	MOISTURE-STRESSING ASPECTS (AND RELIEF ASPECTS) OF RETROFIT MEASURE
Envelope Insulation	Reduces air change, increasing RH* (but increases indoor surface temperatures and reduces condensation and mould potentials...)
Basement Insulation	Cools foundation: condensation potential, and rate of deterioration of wood and concrete itself, may increase. (But seals off inward air leaks and capillary migration of moisture, thus reducing moisture sources feeding indoor air.)
Conversion to flueless heating; sealing off flues	Reduces air change, increasing RH*. Decreases depressurization indoors, promoting more exfiltration of more humid air.*
Window and door retrofit or airtightening	Reduces air change, increasing RH*. (But tends to increase temperature of inner pane, reducing condensation, and reduces condensation on outer pane.)
General airtightening	Reduces air change, increasing RH*. May decrease depressurization indoors, promoting more exfiltration, through hidden leaks, of more humid air.* May reduce drying action by decreasing or blocking infiltration around header joist and sills...* (But restricts at least the visible leaks into envelope, blocking these potential contributors to concealed condensation.)
Ventilation through heat pump heat recovery device (recovering heat from exhaust air; acts as net heater)	May reduce indoor surface temperatures at spots by promoting depressurization/infiltration, increasing potential for condensation and mould*. (But promotes air change, decreases RH, reduces exfiltration and envelope wetting, and increases infiltration and its envelope-drying effect. Comprises a relief measure as well as energy conservation.)
Spot ventilation** (e.g. bathroom fan)	(Relief measure, allowing overall air change to be reduced by other means while avoiding boosting RH.)
Heat recovery ventilation (air-to-air exchanger)**	(Relief measure, controlling moisture and ensuring air change/air quality while keeping air change heating cost below that of air leaky house, if airtightening is also done well.)

* Measure not threatening by itself unless house already marginally airtight and/or moisture loaded.

** Measure does not save energy by itself but allows other steps to save safely.

DEVELOPING THE GUIDELINES, THE MOISTURE ASSESSMENT-PRESCRIPTIVE PROCEDURE

Retrofit measures that change a house beyond the point where it transgresses the "Working Concept" of moisture movement and accumulation will make it prone to significant moisture problems; that's what all of our experience suggests and that's the basis for our draft Moisture Assessment-Prescriptive Procedure or MAPP. Houses are generally resilient, tolerant of considerable moisture-stressing including periods of over-stressing, and eminently correctable where safety margins are exceeded. Therefore our MAPP need not be thought of or used as a precise instrument. (It probably could be close to that, if it included a costly array of testing and monitoring, but precision is unnecessary and costliness would defeat the MAPP's rationale: it wouldn't be used.)

Working Concept. Described in our earlier paper, the Working Concept can be restated briefly here for convenience:

- Indoor Relative Humidity, above a certain level through much of the winter, is the fundamental prerequisite of condensation moisture problems essentially anywhere in the house or its envelope structure.

The critical level may be defined well enough as the RH where the dew point of the indoor air is at or above the temperature of the sustained coldest indoor surface, which may be taken as the indoor window surface (double glazing) at the mean daily minimum temperature in January. This definition may shift a little as the work progresses.

- Wall spaces are not seriously wetted, inland, unless excessive RH is accompanied by gross leaks, retarded drying and flueless heating. In coastal areas, however, walls may be seriously wetted if excessive RH is accompanied by any two of the last three conditions.

- Roof spaces are not seriously wetted, on the coasts, unless excessive RH is accompanied by gross leaks and decidedly inadequate venting. Inland, however, serious wetting may ensue from excessive RH and either one of the last two conditions.

Draft MAPP. The job is to predict the effects of retrofit and ensure that the foregoing conditions are not created. The MAPP is intended to be applicable by contractors offering such appreciable energy-related retrofits as complete new windows, re-siding, general airtightening, retro-insulation, or heating conversions; and by those offering related advisory services or trouble-shooting services.

In line with the Working Concept, the main tasks of the MAPP are the estimating of winter air change flow rate, moisture source strength (MSS), and thence the resulting RH. The MAPP's sub-routines should enable the contractor to assess and predict these for most houses without recourse to fan depressurization or other costly test procedures. The mathematics underlying the sub-routines are somewhat complex but the final tools - the sub-routines - are developing in remarkably user-friendly form.

Air change (AC) is estimated graphically. An approximate ELA (Equivalent Leakage Area) is assigned first, reflecting the house's construction and observed leakiness condition. (Figure 1 is a draft illustration of the mean ELA characteristics of types of house construction in Canada: a starting point for estimating airleakiness. This approach seems to be working; in marginal or indeterminate cases the standard fan depressurization test would be suggested to add confidence.) Further graphs then suggest the January average air change, distilling the LBL procedure[1] to reflect house height, ELA, exposure, and the particular climatic regime. Corrections for flues and fans are then superimposed in equally simple manner.

Moisture source strength, MSS, is then approximated from tables that reflect number of occupants, hours in the home, and certain habits and house characteristics including use of "direct removal" (exhaust fans, dryer vents). As well, an appraisal of possible below-grade sources is also undertaken since these can be substantial contributors in some cases[2].

From the above two inputs, AC and MSS, a graph then predicts the resultant relative humidity as a January average, reflecting the particular regional climate and the day/-night temperatures maintained in the home. The contractor using the MAPP then checks that against the approximate actual RH as revealed by the complaint history and telltale history of the house, relying on window condensation patterns (extent and time period) in particular. Interpretations are tabulated and/or graphed for him.

In addition, the contractor also looks for air leaks into roof spaces and exterior wall spaces, distinguishing gross leaks from normal construction leaks and determining which gross leaks can be plugged economically and which cannot. He also checks for water leaks from windows into wall spaces - which are all too common with certain windows - and water leaks from eaves, valleys, crickets or other flashings, and joint or drip edge details, into roofs or walls. He then assesses the entrapment characteristics of wall exterior planes and roof spaces. Basements tend to operate as unique domains in themselves; a separate set of guidelines is being developed by Dr. Eyre of the Saskatchewan Research Council.

Schematic of the Draft MAPP. Figure 2 illustrates the MAPP from the beginning, following through the assessment-predictive routine and then the prescriptive. The key to judicious prescription is in the degree and manner of re-balancing required to maintain a house under the critical level of RH. Two examples illustrate this prescriptive approach:

i) If a house in St. John's has an actual or firmly predicted RH of say 35%, while its critical RH is say 45%, then it may be said to have a positive safety margin of about 30% ((45 - 35)/35). It is ready for any amount of energy retrofit as long as it will not raise its RH (by airtightening or otherwise reducing air change, and/or by raising MSS) by more than 30%, say. If energy retrofit were desired to greater degrees which would tend to raise the RH by 40% (e.g. full airtightening including windows, plus conversion to flueless heating) then preventive measures would be indicated to pull it down by 10% or more. All percentage changes refer back to the base house which is represented by its presently known or predicted RH.

ii) If the house's known or predicted RH were 55%, the house has a negative safety margin of about 20% ((45 - 55)/55). If the contractor/advisor is simply on a trouble-shooting job, the prescriptive procedure could be used simply to re-balance the house: the contractor would show the householder the group of preventive measures that would reduce RH by 25% and help select the one or two which best fit the house and circumstances. However, if the householder were interested in energy conserving measures that would themselves increase RH a further 20%, the contractor would help the householder to select from a group of preventive measures that would reduce it by a full 30% or more (superceding the re-balancing just mentioned).

On the schematic, "PM 1" refers to the group of preventive measures that each can be tailored to provide a 10% reduction in RH by increasing air changes or reducing MSS, and so on; while the "EM's" are energy conserving measures grouped according to their tendency to raise RH by given proportions. The contractor and householder can select from the group listings, then the contractor tailors the PM's to the house according to the house characteristics and the householder's EM plans or desires. The contractor then runs the modifications through the assessment-predictive routines to check and allow finer tuning of the whole.

Looking at the schematic again, in Figure 3, we indicate that most cases may be handled well enough in a short-cut procedure, if the safety margin is ample. If, say, the house is of known air-leaky construction, harbors just two or three people, has a dry basement and has no telltales or history of moderately high RH, then it is pre-cleared for practically any amount of energy conserving retrofit; if the case is of somewhat tighter construction it may still be pre-cleared for new windows or further airtightening or other "EM 1" retrofits. A simple "Base MAPP" sheet is being developed to allow such short-cut assessments. In any case, the RH balancing is not the whole story: the guideline appraisals of gross leaks, basement conditions and regional effects must also be carried through, depending in part on how much and what kinds of energy retrofit are anticipated.

Of course, the MAPP is just as useful (and more sure-footed) in the trouble-shooting of houses with existing moisture problems. In that usage, the preventive measures are prescribed as corrective measures, but they are in fact the same measures.

Preventive Measures. The term denotes those measures deployed to avoid future moisture problems or to correct existing ones, as just mentioned. Some are also energy-conserving measures in themselves, helping prevent moisture problems that might be raised by other energy conserving measures or even by themselves. For example, placing insulation outside a wall can be done in a manner to help prevent moisture build-up in the wall structure even though it may raise the RH indoors by reducing air change. Another example: plugging gross leaks will save energy but can also raise RH and thus the moisture stressing effects indoors, while simultaneously reducing the moisture stressing within the wall.

The MAPP will direct the contractor to a small array of preventive measures, beginning with the least costly and ranging to fairly extensive and expensive provisions. The following examples of the range of preventive measures are each put forward as if moisture over-stressing has called for its specific use through the MAPP identifying-prescribing routine. They are not yet grouped in "PM 1" or further groupings. The evaluation of their efficacy is underway, with knowledge on hand sufficient for our purposes.

- Correct the More Obvious Errors in House Set-up and Operation. Kitchen or bath exhaust fans may be ducted into the attic; humidifiers may be set to run practically full time through the winter; rain-leaders may be directing water against the foundation and thence in through obvious cracks; roof shingles may be trimmed too closely to the fascia. The MAPP's inspection and data-gathering section will itself serve as a checklist in identifying areas where corrections may be recommended.

- Plug Gross Air Leaks Leading Into the Envelope. Attic hatches, or doors into attic stairwells, may be extremely poorly fitted or open or non-existent. Stair stringers against outside walls may not be plastered-in or otherwise closely abutted to the rough interior finishing. Radiator mounts, pipe intrusions, bathtub closures to the wall and so on may present gross leaks. Such construction deficiencies are worth correcting where they can be identified and accessed economically.

- Seal or Deflect Water Leaks and Back-Splash. Window sill corner leaks and/or lack of drip edges or kerfs, chimney flashing leaks,and damaging back-splashing at steps, decks and so on should be identified by the MAPP and corrections specified. The inspection checklists will address these.

- Reduce Moisture Source Strengths at Source. This group of preventive measures includes the covering of dirt floors of crawl spaces and cellars (e.g. polyethylene plus sand or gravel), provision of floor drain covers or the filling of existing traps, sealing below-grade openings and cracks, re-sloping the surrounding grades away from the foundation, opening plugged perimeter drains and so on. In unusual cases, the preventive measures might include recommendations to change moisture-generating activities (e.g. top-of-stove cooking, showering vs. bathing) where the costs of the following measures are considered less attractive or feasible than the alternative of producing less moisture.

- Strengthen the Direct Removal (DR) Provisions. Preventive measures in this group may include recommendations to use the kitchen and bath fans whenever appropriate or to provide these where they do not exist. Unplugging flues, or opening their cleanouts, or opening wood stove draughts or cleanouts, may be options where the basement is suspected to be a moisture source. Leaving the sill and header area somewhat air-leaky may go hand in hand with that, where basement sources are clearly troublesome and the space is not used as heated living area. Venting clothes dryers,laundry areas and moisture-generating hobby rooms are other DR options that may raise the overall air change, and the heating bill, rather little. The use of dehumidifiers as a summer DR option for the basement will be called up somewhat frequently.

- Increase Air Change Flow Rate Passively. Wedge open the flappers of kitchen, bath and other exhaust fans. Provide supply vents. Install dummy flues drawing from moisture source points and from the house proper; control with a humidistat. These are all options where the need for faster air change is clear. Traditional degrees of depressurization can also be reinstated in this manner, to help reduce exfiltration-condensation in wall and roof spaces, as flues have done for hundreds of years.

- Modify the Envelope to Tolerate Higher RH. Triple glazing; or the use of baffles to improve air circulation over the indoor surface of existing double glazing; blocking air infiltration under the insulation over the top plate;

installing louvred doors to improve warm air circulation through closets; moving furniture away from walls or otherwise improving war air circulation in room corners and so on: these options may be called up where the occupants want to maintain moderately high RH, or cannot reduce MSS and do not want or need more air change.

In such cases the attention to air leaks may have to be taken further than simply finding and plugging gross leaks to protect the envelope. Especially if air sealing of normal crackage cannot be done well, or if there are any concerns about wall entrapment or roof space venting, then the provisions for depressurization of the house to traditional levels becomes most important.

- Mechanical Ventilation. Where mechanical ventilation is called for, the economic options start with the provision of an outdoor air duct to the existing cool air return. (The pressurization effect and the attendant risk of air leakage into walls must then be seriously considered, particularly in coastal areas.) Where the house does not have warm air heating, mechanical ventilation may still be as simple as a single exhaust fan controlled by a humidistat, together with dampered supply inlets (unless the house remains leaky enough) to allot enough supply to and through the various rooms on the way to the exhaust. The resulting depressurization will protect the envelope but may cause uncomfortable draughts. The question of flue backdrafting must be considered with special care in such arrangements[3].

Serious moisture problems in electrically heated houses in Newfoundland have been remedied by such simple ventilation, using a quiet attic-mounted fan controlled by a humidistat. Saturated walls dried out over a six month period and stayed dry; indoor problems and air quality complaints disappeared; the calculated and reported effects on the heating bill were small (private industry references on hand). Technically the MAPP may stop at this level of recommendation. The more sophisticated steps to fully ducted systems, heat pump heat recovery from the exhaust air, or extensive airtightening plus heat exchanger recovery, can perhaps be listed but left outside the province of the MAPP. That avoids the need to project or predict economic justification for these options, leaving recommendations on such devices to others while the MAPP deals with the avoidance of moisture problems.

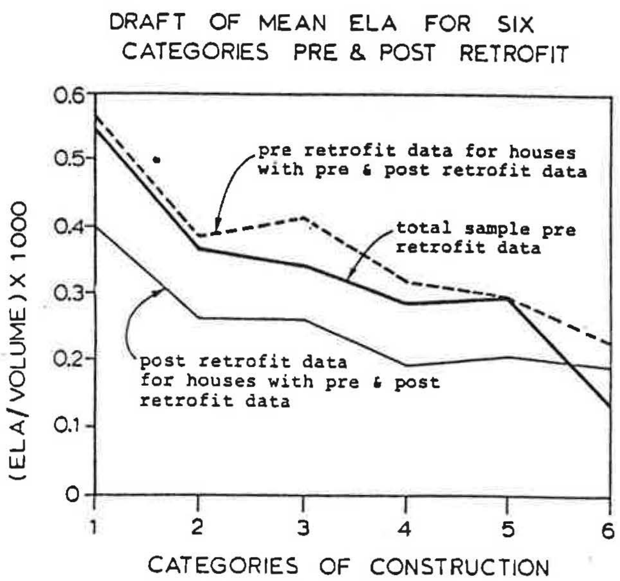

FIGURE 1: AIRTIGHTNESS CHARACTERISTICS OF HOUSE CONSTRUCTION TYPES

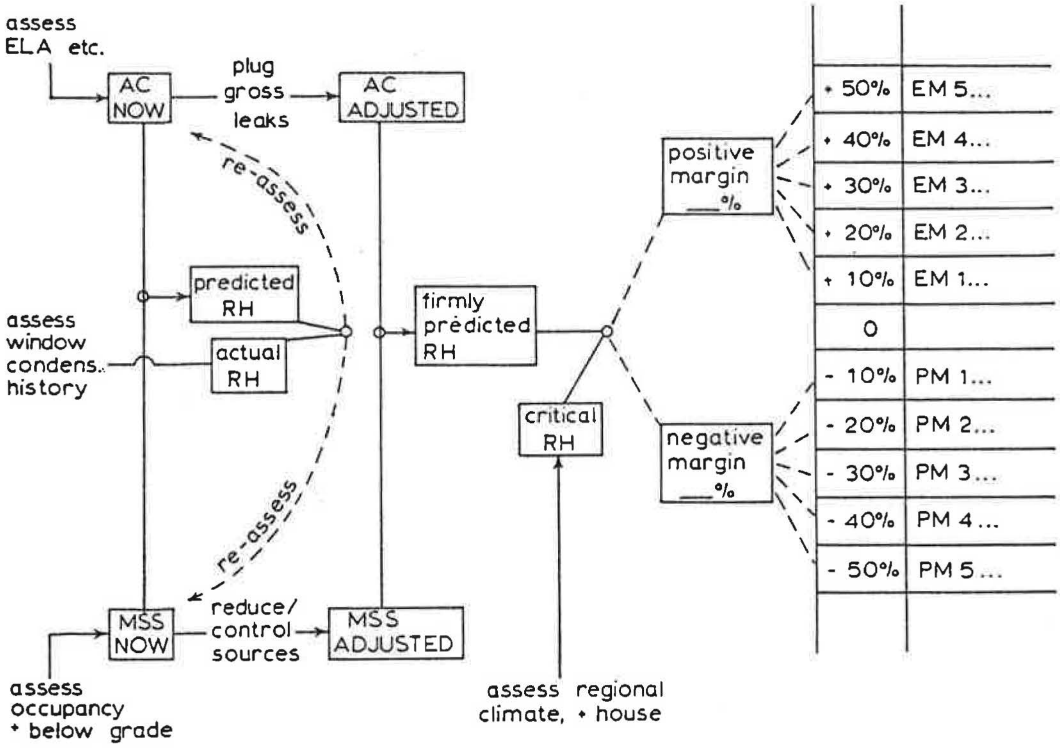

FIGURE 2: SCHEMATIC OF MOISTURE ASSESSMENT PRESCRIPTIVE PROCEDURE

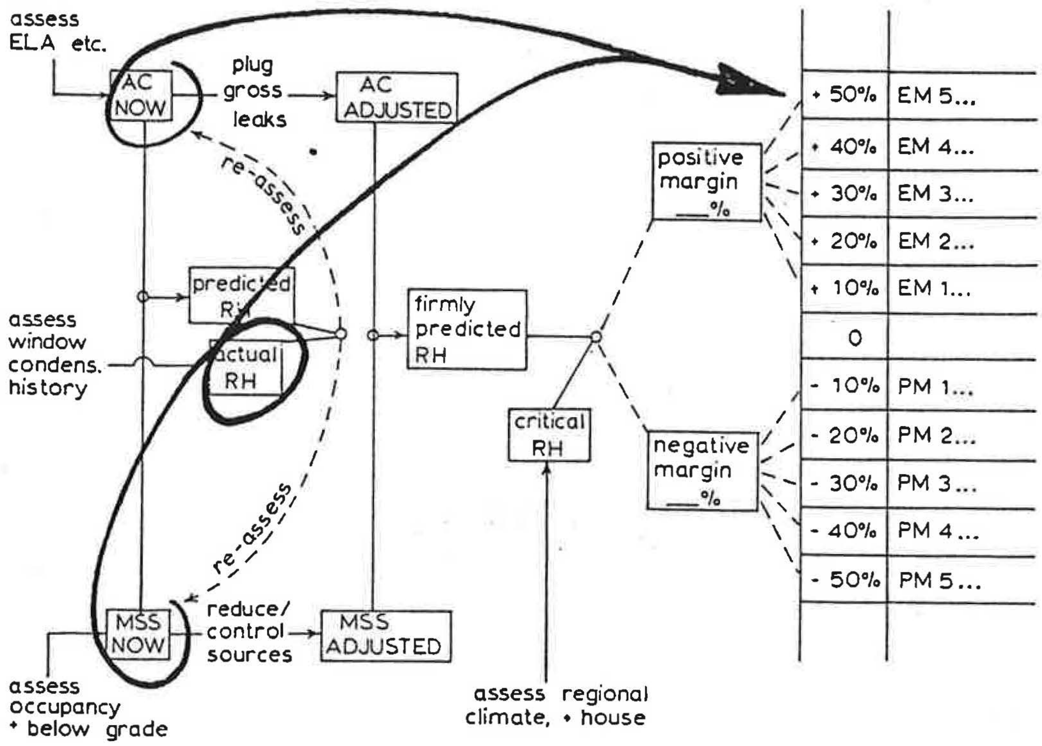

FIGURE 3: SHORT-CUTTING THE MAPP WHERE SAFETY MARGIN IS AMPLE

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